KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

SCHOOL OF GRADUATE STUDIES

A THESIS SUBMITTED TO THE DEPARTMENT OF ANIMAL SCIENCE, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF PHILOSOPHY (MPHIL), ANIMAL BREEDING AND GENETICS

INFLUENCE OF NAKED NECK AND FRIZZLE GENES ON THE QUALITY CHARACTERISTICS OF FRESH AND STORED TABLE EGGS

BY

DAWOLOR NUSUE KANASUAH

(BSc. Agricultural Science)

SEPTEMBER 2016.

DECLARATION

I hereby declare this submission as my own work towards the Master of Philosophy (Animal Breeding and Genetics) and that, to the best of my knowledge, it contains neither material previously published by another person nor material which has been accepted for the award of any other degree of the University, or elsewhere except for some due recognitions that have been made in the text.

Dawolor Nusue Kanasuah	……	……..
Student Name	Signature	Date

Certified by:

…….	……	……..
Supervisor	Signature	Date

Certified by:

…….	……	……..
Head of Department	Signature	Date

ABSTRACT

A study was carried out to determine the influence of the naked neck *(Na*) and frizzle traits (*F*) on the internal and external quality characteristics of table eggs. Normal feathered birds were used as the control. A total of 864 table eggs (288 each) collected from naked neck (*Nanaff*), frizzle (*nanaFf*) and normal feathered birds (*nanaff*) were used in the study. The birds were kept at Akate Farms in Kumasi Ghana. A Completely Randomized Design (CRD) in a 3x2x4x2 factorial was applied on the three phenotypes, two storage temperatures (Room 26^{o}C and Refrigerator 5^{o}C), four storage durations (7, 14, 21 and 28d) and two storage methods (with or without vegetable oil application on the eggs). Egg weight, egg length, egg width, albumen height, albumen weight, shell thickness, shell weight, yolk height, yolk weight, yolk diameter, yolk colour and Haugh unit were the characteristics studied. Proximate composition and nutritional values of table eggs from the three phenotypes were determined as well. Naked neck (*Nanaff*) recorded significantly ($p<0.05$) thicker shell (0.31cm) than frizzle (*nanaFf*) and normal feathered (*nanaff*). Frizzle (*nanaFf*) also recorded significantly heavier yolk weight ($p<0.05$) than naked neck (*Nanaff)* and normal feathered (*nanaff)*. The lowest shell thickness was recorded for eggs stored at room temperature for 28days. Eggs stored with vegetable oil application recorded significantly higher ($p<0.05$) values for albumen height, albumen weight, egg weight, yolk weight, yolk colour, yolk height and Haugh unit than those eggs without vegetable oil application during storage. Albumen height, albumen weight, yolk height and yolk weight values for eggs stored in a refrigerator were significantly higher ($p<0.05$) than the corresponding values for eggs stored under room temperature. Naked neck eggs stored in a refrigerator for 7 days recorded significantly ($p<0.05$) higher egg weight values as compared to those of frizzle eggs and normal feathered birds stored in a refrigerator for 7 days, while normal feather recorded higher eggs weight values than frizzle. Eggs stored in a refrigerator with vegetable oil application from 7 days to 28 days recorded higher yolk height values ($p<0.05$) than those eggs stored under room temperature with vegetable oil application from 7 days to 28 days. It can therefore be concluded that naked neck and frizzle genotypes influence egg quality characteristics under hot and humid environmental conditions. And that refrigerator and vegetable oil maintain better egg quality during storage.

DEDICATION

Many glories and honors to our everlasting God of every story for a successful study. This work is dedicated to my lovely parents Mr. and Mrs. Mulbah K. Jackson, Mr. Timothy O. Kanasuah, Mrs. Laura K. Tamba, Mr. Williams S.Y. Tamba, and the rest of my brothers and sisters. A special dedication to Miss. Gloria A. Bishop who has been like a mother to me in this struggle, and most importantly, my beloved wife Mrs. Hellina K. Kanasuah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGMENT

May the Lord God Almighty be glorified for His tender mercy, strength, wisdom and guidance granted to me in completing this important work. I am greatly indebted to Dr. Oscar Simon Olympio and Dr. Kwaku Adomako for their tireless efforts, positive direction and criticisms leading me to a successful completion. Many thanks to the Akate Farms and Trading Company Limited for making available table eggs of the experimental birds required for purchase. My sincere gratitude to the Excellence of Higher Education for Liberia Development (EHELD) through RTI International USAID for sponsoring me through this program. I am always grateful to Miss Gloria A. Bishop who is like a mother to me bringing me this far. I am also grateful to Mr. and Mrs. Arthur and Sonnie Cooper who have added some values to my life from childhood up to present. I highly appreciate Mrs. Charlene K.J. Freeman who is like a sister to me through assistance. I take this time to acknowledge all faculty, senior staff and laborers at the Animal Science Department, KNUST, for their various ways of making this work a successful one.

LIST OF ABBREVIATION

ACIAR	-	Australian Centre for International Agricultural Research
Nanaff	-	Naked Neck
nanaFf	-	Frizzle
nanaff	-	Normal Feather
P-Value	-	Probability Value
SEM	-	Standard Error of Measurement
USDA	-	United States Department of Agriculture

CHAPTER ONE

1.0 INTRODUCTION

Eggs contain nutrients which are essential for improving our health. These nutrients include proteins which are necessary for the proper maintenance and functioning of the entire body. The body does not function properly if it lacks the essential amino acids. Haney (2008) reported that chicken egg whites and egg yolks contain amino acids. The U.S. Department of Agriculture (USDA) (2008) reported that eggs are rich foundations of minerals and vitamins.

A complete egg is composed of various elements, namely the shell (exterior shell membrane and interior shell membrane), albumen (internal, external and mid albumen), air cell, cuticle or bloom, chalazae, germinal disk, nucleus of pander, yolk and vitelline membrane EDINFORMATICS (2013).

Egg quality is built upon a number of traits including, albumen height, albumen weight, yolk height, yolk diameter, yolk index, yolk weight, shell ratio, shell thickness, shell weight, egg length, egg weight, egg width, and Haugh unit (Khurshid *et al*., 2003). Egg length, egg weight and egg width are the factors which can be determined before the egg is broken. The rest of the parameters are regularly determined after breaking the egg. Farooq *et al*. (2001b) reported that there was positive correlation among shell weight, egg weight and shell thickness of eggs produced by Japanese quails. Farooq *et al*. (2001a) likewise reported a significant and positive relationship among egg weight, egg width and egg length of eggs produced by Fayoumi birds. External factors including cleanliness, freshness, egg weight and shell weight are those characteristics that are important for consumers' acceptability of eggs (Hamilton, 1982). Internal characteristics such as yolk index, Haugh unit and chemical composition are also important in poultry breeding because of their influence on growth of the chicks, breeding performance and egg quality. The external and internal quality traits of

eggs of both hens and quails have significant effects on the hatchability of fertile eggs, and on the weight and development of chicks. In the processing enterprises, the weight of egg shell, yolk and albumen affect price of the product.

The external and internal egg qualities are also influenced by storage duration and storage temperature. Eggs store at low temperature maintain better egg quality. Robinson (1987) reported that changes in egg quality were influenced by the moisture and evaporation of air through shell pores and carbon dioxide (CO_2) escaping from the albumen due to increase in storage temperature. Eggs are able to maintain qualities when stored for a short period of time. Longer storage time gradually deteriorates egg quality. Tebesi *et al*. (2012) reported that eggs were able to maintain higher yolk height when stored within 7days. The application of oil on egg shell has the ability to greatly maintain the quality of the egg during storage. Tanabe and Ogawa (1979) reported that coating eggs with vegetable oil or mineral oil was more effective than with sucrose-fatty acid ester emulsion to keep interior quality of eggs.

Bordas *et al*. (1980) studied the effect of the naked neck gene on egg quality under high and moderate ambient temperature. They reported that the homozygous (*NaNa*) phenotype had significantly ($p<0.05$) more albumen than the heterozygous (*Nana*). Zein El-Dein (1981) observed that shell weight for the heterozygous (*Nana*) phenotype was higher than that of the homozygous (*NaNa*) under the environmental conditions in Egypt. However, Abdel-Rahman (2000) reported that egg shell percentage of *Na* gene was reduced by 0.8% for the homozygous and 4.4% for the heterozygous under an improved and normal environmental condition. The naked neck (*Na*) and frizzle (*F*) genes among dwarf phenotypes (*dwdw-Ff-Nana*) did not considerably affect albumen height at 60 to 76 weeks of age, yolk weight at 76 weeks and shell breaking strength at 60 weeks (Zulkifli *et al.,* 1992). Zulkifli *et al.* (1992) also stated that the combination of naked neck (*Na*) and frizzle (*F*) in non-dwarf phenotype background (*DwDw-Nana-Ff*) seemed to have positive effects on numerous egg quality traits.

Many researches have been conducted about egg quality traits for frizzle, naked neck and normal feathered birds in Sub-Saharan Africa and the world at large. However, these researches have not focused on the nutrient content of the eggs produced by the birds. The interactions of storage methods and the quality traits of eggs produced by these birds have also had very limited focus. For these reasons the objectives of this research were:

1. To determine the influence of frizzle and naked neck genes on external and internal quality characteristics, including amino acid profile and proximate composition of table eggs.
2. To find out the effect of different storage temperatures (5^{o}C and 26^{o}C) and storage durations (7days, 14days, 21days and 28days) on external and internal quality characteristics of table eggs of frizzle, naked neck and normal feathered birds.
3. To study the effect of coating eggs with vegetable oil on external and internal quality characteristics of table eggs of frizzle, naked neck and normal feathered birds.
4. To determine the interactive effects of genotype, storage temperature, storage duration and coating of eggs with vegetable oil on external and internal quality characteristics of table eggs of naked neck, frizzle and normal feathered birds.

CHAPTER TWO

2.0 REVIEW OF LITERATURE

2.1 THE EGG

EDINFORMATICS (2013) defined egg as incompletely sphere-shaped or ellipsoidal body produced by birds, snakes, insects and other animals, housing the embryo during its development. EDINFORMATICS (2013) further listed the external and internal parts of an egg and their functions as;

EGG SHELL: The outer shell is made up of calcium carbonate ($CaCO_3$) and contains as many as 17,000 tiny pores. It is a membrane which is semi permeable, permitting moisture and air through its pores.

EXTERIOR AND INTERNAL SHELL MEMBRANES: These tissues surround the albumen within the shell. They serve as defense against invasion of bacteria and partially made up of keratin. The outer shell tissue within the egg is attached to the egg shell while the inner tissue is connected to the albumen. The egg is warm as soon as it is laid. After the egg freshens, the contents weaken, and the inner membrane separates from the outer membrane, forming an air cell.

CHALAZAE: They serve to keep the yolk in a central position, while twisted in opposite directions. The egg is always fresh, as long as the chalazae remain prominent.

EXTERIOR ALBUMEN: It is a narrow liquefied layer next to the shell membrane.

MIDDLE ALBUMEN: It is also known as chalaziferous layer, which is a solid tangled, tough capsule of albumen round the vitelline membrane of yolk. This tangled tough capsule culminates at each end in the chalazae, and are twisted in opposite direction, which serve to keep the yolk in centered position. The middle albumen is an excellent source of protein and

riboflavin. It stands higher and spreads less than the exterior albumen when the egg quality is high. And it looks like thin white in low-quality eggs.

VITELLINE MEMBRANE: It is a strong covering which encircles the yolk of an egg. The influence of the vitelline membrane is actually significant in that it avoids egg yolk from mottling.

NUCLEUS OF PANDER: It is made up of a plug of whitish yolk, which does not have specific importance for development, but it has pure nutritive function just like the rest of the yolk.

GERMINAL DISK (placoderm): A small, circular, white spot located on the surface of the yolk, it serves as entry of sperm cells into an egg. The nucleus of the egg is located in the blastodisc. The embryo develops from the germinal disk and gradually sends blood vessels into the yolk to be used for nutrition as the yolk develops.

YELLOW YOLK: A chief source of minerals, vitamins and nearly half of the protein and all the cholesterol and fat in eggs. These vitamins and minerals include, calcium, vitamin A, vitamin D, iron, phosphorus, thiamine, and riboflavin. The lecithin is an effective emulsifier produced by the yolk. Yolk colour categorizes from a sunny yellow to a deep orange with regard to the breed of the hen and feed.

WHITE YOLK: It is identified as the latebra, an area located in the center of the yolk. The fat content is lower, which makes it appear as a bright white area in magnetic resonance images. It has an uncertain function but might perform as a dominant structure around which the additional layers of the yolk are formed.

AIR CELL: The air cell is a space located between the inner and outer membranes at the larger end of the egg. As egg gets older, carbon dioxide and moisture leave the egg through the pores of a shell. Air enters to replace them making the air cell becoming larger. Air space is formed when egg substances contract after cooling as the egg is laid.

CUTICLE OR BLOOM: Shell uterus of the oviduct produces the egg shell, and it is made up of the bloom or cuticle, and an outer coating. The cuticle functions in reducing moisture losses and preventing bacteria from penetrating the egg shell by sealing the pores. Washing of the table egg mechanically removes most of the cuticle (EDINFORMATICS, 2013).

2.2 IMPORTANCE OF THE EGG

Varieties of species of female animals including amphibians, birds, fish and reptiles lay eggs. Humans have consumed these eggs for thousands of years. Eggs from birds are made up of a defensive egg shell, albumen and yolk restricted within various thin membranes. The general choices for egg consumption include; chicken, caviar, duck, quail, and roe but chicken eggs are mostly consumed by humans (USDA, 2009). The United State Department of Agriculture also reported that notwithstanding the nutritional value of eggs, there are some possible health problems like individual allergies and storage conditions. Chickens including other egg-laying creatures are generally kept throughout the world. About 62.1 million metric tons of eggs were produced globally from an over-all laying flock of roughly 6.4 billion hens, in 2009 (USDA, 2009).

The Medstar Georgetown University Hospital (2009) observed that the body needs essential amino acids in order to functions well. They also noted that egg yolk and albumen are complete in protein containing the essential and non-essential amino acids, describing egg as a good source of minerals and vitamins. Albumen was also described as a great source of carbohydrates.

Ogunwole *et al*. (2015) reported that chicken eggs are comprised of carbohydrates, easily digestible fats and minerals, high-quality proteins, and valuable vitamins as well. In developing countries, refrigeration of eggs is infrequently practiced and eggs produced are stored provisionally at room temperature till they are sold to the final consumer.

Beside direct human consumption, eggs are valuable raw materials for the cosmetic and pharmaceutical industries, because of their multifunctional properties such as emulsifying, foaming and gelling, which are highly dependent on interior and exterior characteristics (Ogunwole *et al*., 2015).

2.3 EGG QUALITY

Ogunwole *et al*. (2015) defined quality as those traits of eggs that make them acceptable to consumers such as albumen index, freshness, cleanliness, yolk index, shell quality, weight, Haugh unit and chemical composition. They further noted that egg quality is influenced by breed, climatic factors, management, nutrition, and post-lay handling practice. Eggs remain extremely vulnerable to internal deterioration throughout storage, which is dependent on the internal content and shell. Issues that are linked with the level of quality loss in eggs include; air movement, handling, humidity, time and temperature (Ogunwole *et al*., 2015). Oluyemi and Roberts (2000) considered egg quality as the term used, in general, to describe both external and internal quality factors which include, albumen height, egg length, egg weight, egg width, egg index, shell weight, shell thickness, Haugh unit, yolk height and yolk index. Stadelmam (1977) also defined egg quality as traits of an egg that make consumers to accept it for consumption and important factors contributing to the price of table and hatching eggs.

Islam *et al*. (2001) observed that the future generations of birds and their performance are affected by their egg quality traits. Tumova *et al*. (2007) stated that albumen quality, egg shape index, yolk and yolk index are significantly affected by the genotype. Likewise,

Yakubu *et al*. (2008) discovered important differences between normal feathered and naked neck birds in all of the parameters of eggs except shell weight and yolk index. Peters *et al*. (2007) and Kul and Seker (2004) also observed egg weight and egg index as elements of egg resistance to cracking and are considered very important traits when eggs are packed in containers.

2.4 ALBUMEN

The egg albumen, commonly named egg white, is the pure liquid contained within an egg. The albumen could be made from coatings of secretions from the anterior section of the hen's oviduct during the passage of the egg. The albumen may consist of about 90% water into which protein is dissolved. It might contain little fat and carbohydrate content may be less than 1%. It may also cover 50% of protein or just above (USDA, 2000). Samli *et al*. (2005) reported that albumen quality is not only an important factor for egg freshness, but also important for the egg breaking industry because of its market being different from that of the yolk. Samli *et al*. (2005) noted that genetic factors affect albumen quality and that environmental factors such as humidity, storage time, temperature, and the presence of CO_2, are of prime importance in terms of maintaining egg quality. Interior quality of an egg contains microbiological and aesthetic properties which keep yolk and albumen functioning. In newly laid egg, the albumen pH lies between 7.6 and 8.5. During storage, the albumen pH increases up to 9.7 at a temperature dependent rate (Heath, 1977). Leeson and Caston (2003) observed that fresh egg contained 58% albumen, 32% yolk, and 10% shell.

USDA (2000) described four structures that form the egg albumen. The yolk surrounded by chalazae, containing 3% albumen. The inner thin layer which surrounds the chalazae contains 17% of the albumen. The dense layer which provides an envelope or jacket that holds the inner thin albumen and the yolk around the shell membrane at each end of the egg consist of 57% of the albumen. The outer thin layer which lies just inside the shell membrane besides

where the thick white is attached to the shell contains 23% of the albumen (USDA, 2000). Scott and Silversides (2000) observed an increase in albumen height for refrigerated eggs compared to those stored at room temperature.

2.5 THE YOLK

The yolk is that part of the egg which is surrounded by the albumen and it is rich in protein and fat. It also nourishes a developing embryo. Dudusola (2009) observed that water from the albumen is absorbed by the yolk thereby increasing its size as the result of osmotic pressure differences. This causes weakness and expansion of the vitelline membrane which result in the flattening and spotting of yolk. Yolk quality starts to decrease, as soon as the egg is laid and the quality deteriorates with a prolonged storage time. USDA (2000) stated that albumen and yolk chemical structure does not change much under this condition.

2.6 THE EGG SHELL

The shell is that part of eggs with outer hard covering which functions in protecting its internal parts. A thick shell prevents eggs from breaking earlier to hatching which is of key importance to chicken production. The semipermeable membrane permits air and moisture to pass through the egg pores. Ten (10) million Australian dollars was lost per year as a result of low shell quality in Australia in 1998. Evidence attained from ranking services specifies that 10% of eggs was relegated as the result shell quality problems. The egg industry in the USA fixes five major types of egg shell problems: cracks due to thin shell, cracks due to excess pressure, body-checks, shell less eggs and toe holes or pimple. USDA (2000) reported that 78.03% A quality eggs in processing plants had the following types of shell problems; 2.13% colors, 61% pressure cracks, 9.8% pimple and 5.1% toe holes. USDA (2000) also noted that an abnormally high percentage of any type of shell problem will require attention.

2.7 THE EFFECT OF STORAGE TEMPERATURE ON EGG QUALITY

Temperature has been of major importance in improving or deteriorating egg quality during storage. Increase in temperature leads to major deteriorations in egg quality. Xie *et al*. (2002) noted that adequate humidity and low temperature were necessary after oil treatment to maintain good egg quality. Heath (1977) observed that albumen pH for a newly laid egg was between 7.6 and 8.5. Sharp and Powell (1930) after 3 days of storage at 3^{o}C observed an albumen pH of 9.18. After carbon dioxide (CO_2) loss was prevented by oiling the shell, the albumen pH of 8.3 did not change over a 7-day storage period at a temperature of 22^{o}C (Heath, 1977). Li-Chan *et al.* (1995) reported that the pH of albumen reduced from 8.3 to 8.1 in seven days, for oiled egg stored at 7^{o}C. Butcher and Miles (2003a) noted that it would be important to frequently collect eggs in the hot months, and to quickly store eggs in the cool rooms. Robinson (1987) reported that changes in egg quality were influenced by the moisture and evaporation of air through shell pores and carbon dioxide (CO_2) escaping from the albumen due to increase in storage temperature.

2.8 THE EFFECT OF STORAGE DURATION ON EGG QUALITY

Storage time is a major factor for the preservation of eggs for good quality. Tebesi *et al*. (2012) recorded higher shell thickness for eggs stored within one to two weeks. Tebesi *et al*. (2012) also observed higher yolk height for eggs stored within 7days. Raji *et al*. (2009) who observed higher albumen height for eggs stored within 7days as compared to the other storage periods suggested that at a RH above70% might aid in reducing egg weight losses by preserving fresh albumen for a long period of time. Butcher and Miles (2003a) advised that eggs should be separated from other products because they easily absorb odors of the products stored with them as storage time prolongs.

2.9 THE EFFECT OF VEGETABLE OIL APPLICATION ON EGG QUALITY

Vegetable oil application is another storage method for the preservation of egg quality during storage. It is believed to improve the shelf-life of eggs during some length of storage. Oil has the ability to prevent moisture loss from eggs by mean of sealing the egg pores for some length of time. Spamer (1931) noted that Dutch farmers in 1807 first used the method of coating eggshell with oil, and reported that coating with mineral oil greatly improved the shelf-life of the eggs. Tanabe and Ogawa (1979) reported that coating eggs with vegetable oil or mineral oil was more effective than with sucrose-fatty acid ester emulsion to keep interior quality of eggs. Williams (1992) and ACIAR (1998) reported that applying oil on eggs within 24 hours after lay was active in preventing albumen deterioration and it did not replace the need for cool storage.

2.10 OTHER EGG QUALITY PROBLEMS

Butcher and Miles (2003b) identified some key elements affecting internal quality of eggs: age of egg, humidity, disease, storage, temperature and handling. They added that watery albumen is caused by the Newcastle Disease and infectious bronchitis and such condition would continue within a long period after the disease outbreak has been controlled. Eggs stored for several days show weak and watery albumen and the CO_2 loss makes the content alkaline, affecting the egg flavor. High temperatures result in rapid decrease in the internal quality of eggs. Raji *et al*. (2009) observed that storage above a temperature of 15.5^{o}C increases humidity losses.

According to USDA (2000) external quality of egg is judged on the basis of texture, colour, shape, soundness and cleanliness. Egg shell ought to be clean, smooth and free of cracks.

2.11 THE NAKED NECK GENE

The naked neck trait is controlled by a single incompletely dominant gene. Peters *et al*. (2007) observed that the naked neck gene affects feather distribution in chickens. Cahaner *et al*. (1993) also observed that the gene is associated with heat tolerance, making it important for poultry production in the tropics. Local and exotic chickens in South Saharan Africa, including Ghana exhibit diversity in morphological characteristics. Badubi *et al*. (2006) observed some diversities including plumage type, plumage colour, leg feathering and comb type.

The naked neck (Transylvanian) has been bred for more than 200 years (Mou *et al.* 2011). Mou *et al.* (2011) reported that the genomes in naked neck birds contain an extra chunk of DNA on their third chromosomes that boosts the level of protein known as BMP12. Mou *et al.* (2011) added that the gene is more active in the emerging skin from the neck than the other parts of the body. Mou *et al.* (2011) observed that the BMP12 countenance remained enlarged in the naked neck mutant embryo skin from the time the feather patterning originates. After a DNA insertion of 260,000 base pairs away from the BMP12 gene, it was discovered through mapping that the BMP12 gene remained present within the chickens having naked neck mutation, but was not found in the wild-types. This indicates that the BMP12 has an association with chickens possessing the naked neck trait.

2.12 EFFECT OF THE NAKED NECK GENE ON EGG PRODUCTION

Adomako (2009) observed that naked neck birds were superior ($P<0.05$) to their frizzle counterpart in terms of carcass yield, body weight gain, body weight, egg size, number of eggs per clutch, Haugh unit, hen-day rates of lay, shell thickness and economics of production in breeding under intensive, semi-intensive and extensive management systems. Garcês *et al*. (2001) noted that the naked neck gene increased egg size, egg mass and laying rate and concluded that it was due to its association with hot environments. After studying the

effect of the naked neck gene on egg production of Sharkasi birds reared under subtropical environments, Abdel-Rahman (2000) reported that the naked neck gene significantly increased egg mass. Yoshimura *et al.* (1997) stated that naked neck birds among the indigenous chickens remain superior in relation to body weight, egg production and egg size in hot and humid environments. Following studies of naked neck and frizzle genes by Pech-Waffenschmidt (1992), he reported that the interaction of the naked neck and frizzle genes leads to better efficacy of the birds especially in warm humid environments. Adomako (2009) observed that the naked neck and frizzle genes might channel protein which could have been used for feather growth into egg production as a result of the reduction in their feathers. The naked neck gene did not affect number of eggs under a moderate temperature. Heterozygous naked neck (*Nanaff*) layers have significantly higher body weight, egg weight, egg mass, productivity index and egg number than normal feathered birds, under persistent heat (Haaren-Kiso, 1991; Mathur, 2003; Somes, 1998). Nevertheless, Mathur (2003) reported great variance in the naked neck performance in relation to egg mass, body weight, egg number, productivity index and egg weight at various localities in Africa, Asia and the South America.

2.13 EFFECT OF THE NAKED NECK GENE ON MEAT PRODUCTION

Fathi *et al.* (2008) observed that the naked neck birds had bigger breast muscles and higher weight of dressed carcass than the normal feathered birds. Mérat (1990) reported low intramuscular and hypodermic fat in naked neck birds because they utilized a higher portion of energy for thermoregulation. Mérat (1990) further reported that the reduction of plumage cover by 20-40 % provides 1.5-3.0% additional carcass yield to the naked neck genotypes more than their normal feathered counterparts irrespective of the temperature. He stated that due to the high quantity of muscle in the naked necks pectoral region, they have 1.8-7.1 percent extra meat than the normal feathered birds. Mérat (1986) reported that the normal

feathered birds produced lower percentage of meat than naked neck due to the higher amount of muscle in the naked neck birds' pectoral region. Singh *et al*. (1996) reported that the normal feathered birds' weight was 3% less than that of the naked neck through the months of spring and summer with an average temperature of about 32^{o}C. Fathi *et al*. (2008) noted that the normal feathered birds exhibited lower breast muscles, dressed carcass and drumstick than the naked neck.

2.14 EFFECT OF THE NAKED NECK GENE ON MORTALITY

In a survey conducted by Adomako *et al.* (2009) to assess the potential of indigenous naked neck and frizzle birds in Ghana, birds with the naked neck gene had significantly ($P<0.05$) lower mortality than frizzle and normal feathered chickens. Mahrous *et al.* (2008) evaluated the growth performance of the heterozygous naked neck (*Nanaff*) and normally feathered birds and noted that the normally feathered (*nanaff*) hens had significantly ($P<0.05$) greater culling and mortality rates than the heterozygous naked neck (*Nanaff*) birds. Normally feathered (*nanaff*) birds carried a higher mortality rate (74.4%) when compared with all other genotypes (Njenga *et al.* 2005). Kitalyi (1998) came to a conclusion that birds in the tropics carrying the naked neck (*Na*), frizzle (*F)* and dwarf (*dw-nanaff*) genes maintained higher disease resistance than those without these genes. El-Safty *et al.* (2006) observed that naked neck chickens had a better capability to secrete Acute Phase Protein (APP) that offers protection to the birds against infection or any invasion of pathogens. Abdel-Rahman (2000) reported that the average mortality rate of Sharkasi naked neck birds was less than that of normal feathered birds during the laying season.

2.15 EFFECT OF THE NAKED NECK GENE ON EGG QUALITY

Mathur (2003) reported that naked neck birds, under natural conditions, performs better in terms of egg weight, egg mass, egg number, productivity index and body weight in various locations in Africa, Asia and South America. Somes (1998) and Haaren-Kiso (1991) noted

that the naked neck under constant heat stress produced higher body weight, egg mass, egg number, egg weight and productivity index than the normally feathered chickens.

2.16 THE FRIZZLE GENE

Touchburn *et al*. (1980) described frizzle as an incompletely dominant gene which curves the rachis of all feathers such that the feathers curve outward instead of lying smoothly over the bird's body. Horst (1988) also observed that the frizzle gene increased numbers, weight, mass and decreased mortality when the birds were reared under hot and humid environmental conditions. The body feathers together with the wing flying feathers turns toward a dorsal location (Widelitz *et al*., 2007). According to the results of experiments conducted by Chuong (1993) the feather segments from the mature top section reveal rachis of frizzle feathers that contain lesser medulla than the normal leghorn used as controls. Hesse *et al*. (2004) reported that the medulla is contained in the inner ventral section of the rachis and is made up of empty polyhedral pith cells. It was suggested that the frizzle phenotype is initiated by a deficiency occurring in the ventral part of the rachis (Chan *et al*., 2012).

The curved feathers of frizzle chickens all twist outward and upward. They cannot lie smooth touching the body as a result of an altered feather rachis structure and morphology (Patel *et al*., 1999). Chang *et al*. (2004) stated that the frizzle mutation is described to occur as a single autosomal gene symbolized by *F* and it displays an incompletely dominant inheritance.

In an effort to separate the genetic mechanism underlying frizzle feathers, Chan *et al*. (2012) conducted a whole genome linkage scan and mapped the causative genetic mutation to the linkage group E22C19W28_E50C23. By analyzing the candidate genes in the related interval, they recognized that the *F* mutation is introduced by a deletion in a preserved section of an alpha-keratin. They reported that the contributing effect of the KRT75-MT was set by a

retrovirus-mediated inexpression of the wild-type or mutated K75 protein in the feather follicle during regeneration in chickens with normal plumage.

The KRT75 mutations have interestingly been recognized in mammals, causing structural abnormalities in human and mouse hair. This implies the K75 role is fundamental for building the architecture of skin appendages (Widelitz *et al*., 2003).

Horst (1989) reported that the frizzle disorder is produced by a single incompletely dominant autosomal gene which is symbolized by *F*. He further noted that frizzling trait is controlled by the frizzle gene which is situated on chromosome 6. Somes (1998) also noted that the rachises of all feathers in unmodified frizzle birds are extremely curved.

2.17 EFFECT OF THE FRIZZLE GENE ON EGG AND MEAT PRODUCTION

It has been well documented that frizzle along with naked neck males could be used to improve egg production, egg quality and growth rate at ambient temperature of 30^{o}C and more in many Asian countries and sub-tropical climates though the outcome would vary (Mathur 2003). N'Dri *et al*. (2007) and Mahrous *et al*. (2008) observed that the frizzle birds performed better than the normal feather chickens at high ambient temperatures, but similar to the naked neck in terms of meat and egg production. However, there were great changes in the performance of these birds in regard to egg weight, egg number and other productivity indices at various locations.

Adedeji *et al.* (2006) observed that the internal heat is reduced by air passing over the exposed body of birds, granting them the ability to feed more as compared to others stressed by heat, thereby improving laying performance of the frizzle. Mérat (1990) reported that birds carrying the frizzle gene had an increase in egg number under humid and hot conditions. Under high temperature, the frizzle layers performed better in egg production than their normal feather counterparts (Horst and Mathur, 1994).

In all combinations of genotypes, the frizzle genotypes remained substantially ($P<0.05$) greater than the naked neck and normal feathered chickens in terms of disease resistance and it also had least mortality (Oke, 2011). Oke (2011) described the frizzle as a fast growing native bird that can be used for breeding meat type of chickens in the humid tropics.

2.18 EFFECT OF THE FRIZZLE GENE ON MORTALITY AND EGG QUALITY

The frizzle birds had a reduction in mortality, and an increase in egg mass and egg number due the presence of the gene which enabled the birds to endure in hot and humid environments (Horst, 1988). Mérat (1990) indicated that of the frizzling gene increased egg mass, egg number, along with reduction in mortality, when raised in hot and humid environments.

After comparing the frizzle (*F*) gene and the naked neck (*Na*) gene within two controlled settings at normal and high temperatures of 22^{o}C and 32^{o}C, and also in an open-house system in Malaysia with varying temperatures (22^{o}C to 32^{o}C), Horst and Mathur (1994) came to the conclusion that *Na* gene and *F* gene had better results in growth and higher egg yield at high temperatures.

Adomako *et al*. (2010) concluded that better performance of naked neck and frizzle layers might be because of the fact that portions of the dietary protein which should have been used for feather development are used for the formation of eggs in the frizzle and naked neck birds as a result of the reduction in the amount of feathers.

2.19 INFERENCES FROM THE LITERATURE REVIEW

It can be concluded from the literature review that the naked neck and frizzle birds are superior to the normal feathered in many traits including heat tolerance, survivability, egg quality, mortality and egg production.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 LOCATION AND DURATION

The research was conducted at Akate Farms and Trading Company Limited (AFTC) at Saaman, Kumasi, Ghana and the Department of Animal Science, Kwame Nkrumah University of Science and Technology. The research was completed in six months

3.2 EXPERIMENTAL BIRDS AND EGGS

The experimental birds kept at the AFTC were offspring of the cross between naked neck and frizzle males and hybrid commercial Lohmann females. The naked neck and frizzle, both heterozygotes were bred with normal feathered Lohmann Brown classic layers in two separate matting producing offspring which were heterozygous naked neck, heterozygous frizzle gene and normal feathered in the first filial (f1) generation.

Eight hundred and sixty-four (864) table eggs were collected from the three phenotypes. The eggs were collected from the naked neck (*Nanaff*), frizzle (*nanaFf*) and normal feathered (*nanaff*) layers kept as experimental birds by Akate Farms & Trading Company LTD (AFTC) Kumasi, Ghana. The layers were 28 weeks old at the beginning of the experiment. The external and internal egg qualities were determined after collection, using the procedures described by Fayeye *et al.* (2005).

3.3 EXPERIMENTAL DESIGN

A completely Randomized Design (CRD) in a 3x2x4x2 factorial was applied. Eggs were obtained from the three phenotypes *Nanaff* (naked neck), *nanaFf* (frizzle) and *nanaff* (normal), stored at two temperatures room (26^{o}C) and refrigerator (5^{o}C), for four storage durations (7, 14, 21 and 28 days) using two storage methods (with or without the application

of vegetable oil to the egg shells). The Sunny Vegetable oil manufactured in Ghana was applied on the eggs by the method of immersion.

The experiment was conducted on three phases and eggs were collected in a large scale on each phase of the experiment. And each phase lasted from 0 day to 28 day, with day 0 used as a control. The three phenotypes were separated into nine different pens, with each phenotype also being separated into three different pens labelled as treatment (T1, T2 and T3), with about twenty (20) birds in each pen. A total of eight hundred and sixty-four (864) table eggs from the three phenotypes were used in the experiment with two hundred-eighty (288) table eggs obtained from each phenotype using ninety-six (96) table eggs of each phenotype for every phase of the experiment. Twenty-four (24) table eggs from each of the three phenotypes were analyzed on each storage period, method of storage and oil application.

3.4 PARAMETERS OF THE RESEARCH

This research was conducted to determine the effect of naked neck and frizzle genes on the external and internal quality parameter of eggs of birds kept at AFTC. Shell thickness, shell weight, egg weight, egg length and egg width were the external quality characteristics determined. Internal quality characteristics included albumen height, albumen weight, yolk height, yolk diameter, yolk colour, yolk weight and Haugh unit. Proximate composition of the eggs from the three phenotypes was determined. The nutritional value of egg albumen from the three phenotypes was also assessed.

3.5 MEASUREMENT OF PARAMETERS

a. The egg width and length was measured by using a pair of Vernier Calipers (cm).
b. Digital electric balance was used in weighing the eggs.
c. A micrometer screw gauge (mm) was used to determine the thickness of the egg shell.
d. Shell thickness was calculated from the average of three measurements taken at the middle, broad end and the small end of the eggs, with the aid of micrometer screw gauge.
e. A Vernier Caliper calibrated in centimeters (cm) was used to determine the yolk diameter.
f. The DSM yolk colour fan (formerly Roche Yolk Color Fan) was used to determine the colour of the egg yolk. Higher figures indicates deeper yolk colour while lower figures indicate lighter yolk colour.
g. A digital scale was used to determine yolk weight.
h. Yolk height was determined by the use of a tripod spherometer.
i. Albumen weight was also determined by the use of a digital scale.
j. A tripod spherometer was also used to determine the albumen height.
k. Egg weight loss was determined by subtracting the final weight from the initial weight, and then expressed as a percentage.
l. Haugh unit was determined by applying the formula ($HU = 100 \log (H + 7.57 – 1.7W^{0.37})$ introduced by Haugh (1937).

Where

H = Observed albumin height (mm)

HU = Haugh Units

W = Observed weight of egg (g) (Roush, 1981)

H = Thick egg white height (mm)

The proximate composition of the eggs was determined by drying egg samples (albumen and yolk) in an oven at 65^{o}C for 72 hours. The dried samples were transferred to the Crops and Soil Science Laboratory, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology for the proximate composition analyses.

The nutritional value of the eggs was analyzed by Evonik Nutrition South Africa Limited. The albumen was also dried in an oven at 65^{o}C for 72 hours and later transferred to South Africa for the amino acid profile analyses.

3.6 DATA ANALYSIS

The data collected were subjected to analysis of variance (ANOVA) using the GenStat (12th Editions) at $P<0.05$. Differences between means were separated using Duncan's Multiple Range Test.

CHAPTER FOUR

RESULTS AND DISCUSSION

INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE, STORAGE DURATION, STORAGE TEMPERATURE, OILING AND THEIR INTERACTIONS

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE

The effects of phenotype on internal egg quality of table eggs are presented in Table 4.1. There were no significant differences ($p>0.05$) among various phenotypes in relation to albumen height, albumen weight, yolk diameter, Haugh unit and yolk height. The absence of significant differences for these parameters may be attributed to the result of the birds coming from common descent even though they appear phenotypically different with respect to their feather structure and distribution. This result agrees with the findings of Rajkumar *et al.* (2009) who observed no significant differences in albumen height, albumen weight, yolk height, (28 weeks old) and Haugh unit for *NaNa*, *Nana*, and *nana* genotypes in India. Udoh *et al*. (2012) also reported no significant difference ($p>0.05$) among three local genotypes in terms of yolk weight, albumen height and yolk height in Nigeria.

Frizzle (Table 4.1) recorded significantly heavier yolk weight ($P<0.05$) than naked neck and normal feathered birds, with the normal feathered showing the lowest value in this trait. The higher yolk weight value for eggs from the frizzle birds could be due to the results of their feed conversion ratio, converting protein for feather production into their eggs. Yakubu *et al.* (2008) however recorded heavier yolk weight for naked neck than normal. Nwachukwu *et al.* (2006) also reported that naked neck exhibited significantly ($P<0.05$) heavier yolk weight than frizzle and normal feathered birds. Chatterjee *et al.* (2007) recorded higher yolk weights in naked neck, barred desi and frizzle birds and lower yolk weights in brown and black

Nicobari breeds of Andaman. However, Rajkumar *et al*. (2009) recorded a significantly ($P<0.05$) heavier yolk weight for normal feathered birds than naked neck ones in India, and noted that lower yolk weight in naked neck birds indicated lower fat percentage in these birds than their normal feathered counterparts.

The yolk colour (Table 4.1) for naked neck and the normal feathered were not significantly ($P>0.05$) different but both were significantly ($P<0.05$) different from the frizzle which recorded a lower yolk colour value. Islam *et al*. (2001) recorded higher yolk colour values from Bangladesh naked neck chicken which is in agreement with the results of the current study. However, Rajkumar *et al*. (2009) reported higher yolk colour in normal feathered (8.00) and naked neck (7.49) than observed in the present findings.

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY STORAGE DURATION

The effect of storage duration on the internal quality of table eggs is presented in Table 4.1. The yolk colour and yolk weight exhibited no significant ($p>0.05$) difference for all the storage durations.

Albumen height for day 0 was significantly ($P<0.05$) superior to those of day 7, 14, day 21 and day 28. Day 7 was higher than days 14, 21, and 28 in terms of albumen height and albumen weight. There were no significant differences ($P>0.05$) between day 14 and day 21. This result agrees with the findings of Raji *et al*. (2009) who observed higher albumen height for day 7 as compared to the other storage periods. Akinola and Ibe (2014) reported values similar to the findings of the present study. Tebesi *et al*. (2012) however reported different findings, with day 14 showing higher albumen height.

Day 28 showed significantly higher ($p<0.05$) yolk diameter value than day 21, 14, 7 and day 0. The higher yolk diameter values could be due to the expansion of yolk as storage time increases.

Day 0 recorded a significantly higher ($p<0.05$) yolk height than days 7, 14, 21, and 28, but day 7 also recorded higher yolk height value than day 14, 21, 28. The higher yolk height could be attributed to the freshness of eggs at earlier storage period. The current result on yolk height agrees with Raji *et al*. (2009) and Tebesi *et al*. (2012) who reported higher yolk height for day 7.

Day 0 recorded a significantly higher Haugh unit than days 7, 14, 21 and 28, but day 7 was significantly higher in Haugh unit values than days 14, 21, and 28 which did not differ significantly from each other. The decrease in Haugh unit which could be attributed to the deterioration of egg quality as storage duration increases. USDA (2000) reported that higher Haugh unit determines the protein content and freshness of eggs. Akinola and Ibe (2014) presented similar finding with day 7 showing higher Haugh unit than day 14, 21 and 28. The current work is also similar to that of Raji *et al*. (2009) who reported higher Haugh unit value for day 7. Rajkumar *et al*. (2009) also recorded higher Haugh unit value for day 0.

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY STORAGE TEMPERATURE

Results of the influence of storage temperature on internal egg quality is presented in Table 4.1. Albumen height, albumen weight, Haugh unit, yolk height, yolk colour, yolk diameter and yolk weight was significantly ($p>0.05$) affected by storage temperatures. The significant differences in these egg quality traits reveal the influence of storage temperatures on them.

Albumen height was higher for eggs stored in a refrigerator than those stored under room temperature. This could be attributed to the fact that eggs stored in a refrigerator maintain

better albumen quality than those stored at room temperature. Scott and Silversides (2000) observed increased albumen height for refrigerated eggs than the eggs stored at room temperature. Samli *et al*. (2005) reported that albumen of refrigerated eggs was higher than eggs stored at room temperature and other storage methods. Similar findings have been reported by ACIAR (1998). Mountney (1976) suggested that the difference between refrigeration and various storage methods to maintaining egg quality could be due to their varying ability to retard carbon dioxide loss and breakdown of carbonic acid to carbon dioxide, which help egg albumen to maintain its quality during refrigeration.

Albumen weight also showed a significant ($p<0.05$) difference with the albumen of eggs in a refrigerator being heavier (33.88g) than the eggs stored at room temperature (32.59g). The heavier weight of the albumen for refrigerated eggs could be due to the prevention of evaporation of moisture from eggs stored in a refrigerator as a result of low temperature. Mountney (1976) reported that the retention of Mucin fiber in the albumen of eggs stored in a refrigerator prevented the albumen from becoming watery and losing weight. ACIAR (1998) also reported a lower weight loss in refrigerated eggs and suggested that it was the result of less moisture loss from the eggs. Khan *et al*. (2013) noted that albumen quality deterioration could be due to the effect of evaporation of moisture and carbon dioxide from the egg when stored under room temperature.

The mean yolk weight of eggs stored in a refrigerator was significantly heavier ($p<0.05$) than those stored at room temperature. This could be due to the retention of moisture in the yolk of eggs stored in a refrigerator. Samli *et al*. (2005) observed that there was a decrease in yolk weight with increase in storage temperature.

Eggs stored at room temperature showed significantly higher yolk colour value (4.45) than eggs stored in a refrigerator. This has to be investigated further if temperature has a

significant effect on yolk colour. Yolk diameter also exhibited a significant difference ($p<0.05$) with eggs stored at room temperature showing higher yolk diameter than the ones stored in a refrigerator.

Yolk height was significantly higher ($p<0.05$) for eggs stored in a refrigerator than the ones stored at room temperature. This result was similar to the finding of Raji *et al*. (2009) who recorded higher yolk height for eggs stored in a refrigerator than those ones stored at room temperature.

Haugh unit showed a significant difference ($p<0.05$) with eggs stored in a refrigerator recording higher Haugh unit (66.91) than eggs stored at room temperature (50.87). The higher Haugh unit indicates the freshness of eggs stored in a refrigerator as Haugh unit value determines the changes of the interior quality of eggs. Park *et al*. (2003) also recorded a decrease in Haugh unit for eggs stored under high temperature. The present result is similar to that of Dudusola (2009) and Raji *et al*. (2009) who recorded higher Haugh unit values for eggs stored in a refrigerator than the ones stored under room temperature.

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY OIL DURING STORAGE

The effect of the application of vegetable oil on internal egg quality traits is presented in Table 4.1. There were significant differences ($p<0.05$) between eggs coated with vegetable oil and those that were not coated with vegetable oil for the internal quality traits studied. The significant differences could be attributed to the fact that oil has the ability to seal egg pores, preventing evaporation of moisture and carbon dioxide from the eggs during storage.

Eggs coated with vegetable oil had heavier albumen weight and higher albumen height values than those that were not coated with vegetable oil. This might be due to the retention of

moisture within the albumen of oiled eggs in the absence of osmotic pressure as observed by Orji *et al*. (1981).

Eggs coated with vegetable oil were significantly higher ($P<0.05$) in yolk weight value than those eggs stored without vegetable oil and these values could be due to increase of fat within the yolk through absorption. Raji *et al*. (2009) observed lower yolk weight indicating lower fat percentage in the egg.

The yolk colour was significantly higher (deeper) ($p<0.05$) for oiled eggs (4.89) as compared with those stored without oil application (4.55). The significantly higher (deeper) yolk colour value observed for oiled eggs indicates that eggs stored after oil application maintained better yolk colour than eggs stored without oil application. Yolk colour has effect on the nutritional value of eggs.

Eggs stored without oil application showed significantly higher ($p<0.05$) yolk diameter than those stored after vegetable oil application. The higher yolk diameter indicates the spread of yolk as the result of moisture loss from the yolk. This could be attributed to the evaporation of moisture from the eggs during storage as a result of high temperature. The oil helps to seal the various pores on the eggs preventing evaporation of moisture during storage.

Yolk height for eggs coated with vegetable oil was significantly higher ($p<0.05$) than those eggs stored without vegetable oil which indicates that eggs stored with vegetable oil maintain better yolk quality. Raji *et al*. (2009) observed higher yolk height for oiled eggs as compared to those stored under room and high temperatures.

Haugh unit showed a significant difference ($p<0.05$), with eggs coated with vegetable oil showing higher value (63.77) than eggs without vegetable oil (54.00). Güçlü *et al*. (2008) observed Haugh unit similar to the current results in Table 4, with eggs stored with fish oil

showing higher Haugh unit ($p<0.05$) than other storage methods. Dudusola (2009) reported results that were similar to the current study. The current result in Table 4 also agrees with the finding of Grobas *et al*. (2001) who reported significantly ($p<0.05$) higher Haugh unit for eggs stored with olive and soya beans oil.

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE X STORAGE DURATION

The results on the influence of phenotype and storage duration on internal egg quality traits are presented in Table 4.1. Apart from yolk weight, there was no significant phenotype and storage duration interaction for the internal egg quality characteristics studied.

Eggs from naked neck birds had significantly ($p<0.05$) higher yolk weight (Table 4.3) as storage duration increased from 7 days to 21 days; but there was a significant drop ($p<0.05$) in yolk weight when eggs were stored for 28 days. In the case of eggs laid by birds with the frizzle phenotype, yolk weight decreased significantly from day 7 to day 21 but increased significantly when stored for 28 days. There was no difference in yolk weight for eggs stored for 7 days and 28days (17.76/17.74g) for frizzle birds. The yolk weights for eggs from normal feathered birds which were stored for either 7 days or 14 days did not differ significantly ($p<0.05$). Chatterjee *et al*. (2007) reported higher yolk weights in naked neck and frizzle fowl. Yakubu *et al*. (2008) also reported yolk weight (16.95g) in naked neck birds which was similar to the yolk weight (16.95g) for eggs of naked neck birds stored for 28 days in the current study.

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE X STORAGE TEMPERATURE

The effects of phenotype and storage temperature on egg quality of table eggs are presented in Table 4.1. There were no significant phenotype x storage temperature interactions for all the internal egg quality characteristics studied.

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE X OIL APPLICATION

Table 4.1 shows results of the influence of phenotype and oil application on egg quality characteristics of table eggs. The results in Table 4.1 show no significant ($p<0.05$) phenotype x oil application interactions on all the internal egg quality parameters studied except yolk colour.

Naked neck recorded deeper yolk colour ($p<0.05$) than frizzle and normal feathered while normal feathered showed deeper yolk colour than frizzle. The deeper yolk colour could be attributed to the influence of gene on the yolk colour and with the addition of oil through absorption, changing the yolk colour.

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY STORAGE DURATION X STORAGE TEMPERATURE

The effects of storage duration and storage temperature on internal egg quality characteristics are presented in Table 4.1. The results indicate that yolk color showed no significant difference ($p<0.05$) in terms of the interaction of storage duration and storage temperature.

Eggs stored in a refrigerator for all the storage periods showed higher albumen height values ($p<0.05$) than those eggs stored under room temperature. Eggs stored at room temperature for 7 days were also higher in albumen height values than the rest of the storage periods.

Eggs stored under room temperature for 7 days exhibited significantly higher ($p<0.05$) albumen weight but deteriorate from day 14 to day 28, with day 28 showing the lowest albumen weight. The lower albumen weight for 28 days under room temperature could be attributed to high temperature and longer storage time. There was a significant increase and decrease ($p<0.05$) in albumen weight for eggs stored in a refrigerator for 7 days, 14 days and 28 days, with a drop in 21 days. Jin *et al*. (2011) reported that albumen weight significantly decreased with increase in storage time. Okur and Akyurek (2009) reported that yolk and albumen weight did not change within 10 days of storage at any temperature.

Eggs stored for 14 and 28 days in a refrigerator showed significantly ($p<0.05$) lower yolk weight values than 7 and 21 days. There was a dramatic increase and decrease in yolk weight of refrigerated eggs for an unknown reasons. There was also a significantly higher ($p<0.05$) yolk weight values for eggs stored in a refrigerator for 7 days but decreased with increased in storage time. Apart from 7 days, eggs stored under room temperature showed significantly higher ($p<0.05$) yolk weight values (for 14 days and 28 days) than refrigerated eggs but both storage conditions were similar for eggs stored within 21 days. Jin *et al*. (2011) observed that yolk weight significantly increased with increase in storage temperature and storage time which agrees with the current results.

Yolk diameter recorded significantly higher values ($p<0.05$) for eggs stored at room temperature with an increased in storage time. Eggs stored in a refrigerator showed a constant yolk diameter value from 7 days to 21 days but slightly decreased within the length of 21 to 28 days.

Yolk height was significantly higher ($p<0.05$) for eggs stored in a refrigerator for 21 days, than 7 days and 14 days. Day 28 however recorded the lowest yolk height for eggs stored in a refrigerator which could be due to storage time. Yolk height for eggs stored at room

temperature extremely decreased with increase in storage time. Raji *et al*. (2009) recorded significant increase in yolk height with increase in storage temperature and storage time. Yolk height decreasing with increase in storage temperature observed in this study agrees with Scott and Silversides (2000) and Samli *et al*. (2005) who also observed decrease in yolk height with increased in temperature.

Haugh unit values for eggs stored in a refrigerator were significantly higher ($p<0.05$) than the eggs stored under room temperature for all the storage periods. Day 7 and day 14 recorded the highest Haugh unit values for eggs stored in both refrigerator and room temperature than all the storage periods. Smali et al. (2005) also observed higher Haugh unit values for eggs stored at low temperature in early storage periods.

4.1. INTERNAL EGG QUALITY TABLE EGGS AS INFLUENCED BY STORAGE DURATION X OIL APPLICATION

Table 4.1 shows results of the influence of storage duration and oil application on internal egg quality characteristics. The results showed no significant interactions ($p>0.05$) between storage duration and oil application on egg quality in terms of albumen height, albumen weight, yolk weight, yolk colour, yolk diameter and Haugh unit. However, there were significant ($p<0.05$) storage duration x oil interactions in terms of yolk height.

Yolk height recorded significantly higher ($p<0.05$) values for eggs coated with vegetable oil during storage; although the yolk height values slowly decreased with increase in storage time. Eggs stored without oil application rapidly deteriorated in yolk height as storage time increased. The yolk height for eggs with vegetable oil application showed significantly higher values ($p<0.05$) than those without oil application during storage which could be attributed to the fact that eggs coated with vegetable oil maintained better yolk quality during storage. This result agrees with that of Tebesi *et al.* (2015) who recorded higher yolk height values for

eggs stored with oil. The results in this study also collaborates with that of Raji *et al*. (2009) who observed higher yolk height for eggs stored with oil during shorter storage period.

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY STORAGE TEMPERATURE X OIL APPLICATION

Table 4.1 shows results of the interaction of storage temperature and oil application for some internal egg quality traits. The results (in Table 4.1) showed no significant storage temperature and oil application interaction in albumen weight, yolk colour but there were significant ($p<0.05$) temperature and oil interaction effects on albumen height, yolk weight, yolk diameter, yolk height and Haugh unit.

There was a significantly higher ($p<0.05$) albumen height values (Table 4.1) for oiled eggs stored in a refrigerator as compared to eggs stored without oil application under room temperature. The eggs coated with oil stored at room temperature and in a refrigerator also recorded higher albumen values than the ones stored at room temperature and in a refrigerator without oil application. Oiled eggs and non-oiled eggs in a refrigerator also recorded higher albumen height values as compared to those oiled eggs and non-oiled eggs stored under room temperature. This might indicate that eggs coated with vegetable oil and stored in a refrigerator maintained better albumen quality, which could be due to the prevention of moisture loss by evaporation thus retaining moisture in the albumen as the oil seals the egg pores. Dudusola (2009) reported that eggs coated with oil and refrigerated eggs did not lose much solvent as compared with those in polythene bag and control.

Yolk weight for oiled eggs at room temperature recorded a significantly higher ($p<0.05$) value than those ones stored in a refrigerator with oil. The yolk weight of eggs without oil application stored at room temperature also recorded higher value as compared with eggs stored in a refrigerator without oil application. The increased yolk weight during storage at

room temperature could be the result of the movement of water from albumen to yolk due to some high pressures. Orji *et al*. (1981) and Dudusola (2009) observed increased in yolk weight as a result of increase in storage temperature and storage time.

Eggs stored without oil application at room temperature exhibited a higher yolk diameter ($p<0.05$) as compared with eggs with oil stored at room temperature and in a refrigerator. The increase in yolk diameter could be due to the addition of moisture to yolk as a result of increased temperature. Orji *et al*. (1981) observed that result of osmotic pressure differences cause the movement of water from albumen to yolk thereby increasing yolk size.

Yolk height for oiled eggs stored in a refrigerator showed significantly ($p<0.05$) higher value as compared with those eggs at room temperature with oil application. Eggs in a refrigerator without oil application also showed higher yolk height value than eggs stored at room temperature without oil application. This indicates that oil application and refrigeration have positive influence in maintaining good yolk quality during storage. Raji *et al*. (2009) also recorded higher yolk height values for oiled eggs stored at low temperature.

Egg with vegetable oil application stored in a refrigerator showed a significantly higher ($p<0.05$) Haugh unit value than eggs with vegetable oil application at room temperature. The eggs without vegetable oil application in a refrigerator also recorded higher Haugh unit values as compared with those stored at room temperature without oil application; which could be accredited to the fact that the application of vegetable oil prevented the deterioration of egg quality during storage. The results (Table 4.1) agree with that of Raji *et al*. (2009) who also recorded higher Haugh unit values for oiled eggs stored in a refrigerator than oiled eggs stored under room temperature**.**

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE X STORAGE DURATION X OIL APPLICATION

Table 4.1 shows the internal egg quality traits as influenced by interaction of phenotype x storage duration x oil application. The results showed no significant phenotype x storage duration x oil application interaction ($p>0.05$) for all the parameters of internal egg quality traits studied except albumen weight and yolk weight.

Eggs stored without vegetable oil from naked neck for 7 days showed higher albumen weight value (35.84g), while frizzle eggs stored for 7 days with vegetable oil also recorded higher albumen weight value (35.72g). There was some decrease in the albumen weight of naked neck with increase in frizzle egg albumen during storage. While frizzle decrease in albumen weight, naked also increased.

Naked neck (Table 4.1) also recorded higher yolk height value than frizzle and normal feathered when stored for 21 days with vegetable oil. The normal feathered also showed higher yolk height value than frizzle when stored for 7 days with vegetable oil.

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE X STORAGE DURATION X STORAGE TEMPERATURE

The effect of phenotype x storage duration x storage temperature interaction on some internal egg quality parameters is presented in Table 4.1. The result shows that significant ($p>0.05$) phenotype x storage duration x storage temperature interaction was observed for yolk height.

Eggs from the naked neck stored in a refrigerator for 21 days (Table 4.1) showed higher yolk height value ($p<0.05$) than frizzle and normal feathered. This indicates that naked neck maintains better yolk quality than frizzle and normal feathered when stored in a refrigerator up to 21 days. Frizzle and normal feathered also recorded similar yolk weight with eggs

stored in a refrigerator for 7 days. This shows that eggs stored in a refrigerator maintained better yolk quality for these phenotypes during early storage period.

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE X STORAGE TEMPERATURE X OIL APPLICATION

Table 4.1 shows the results of internal egg quality influenced by the interaction of phenotype x storage temperature x oil application and storage duration x storage temperature x oil application on some egg quality traits. Beside yolk diameter, the results in Table 4.1 showed no significant ($p>0.05$) phenotype x storage temperature x oil application interaction in all the internal egg quality characteristics studied.

The naked neck, frizzle and normal feathered normal birds recorded similar yolk diameter values for oiled eggs stored in a refrigerator (Table 4.1). Naked neck and normal also recorded similar yolk diameter values for eggs with vegetable oil application stored at room temperature, which were slightly higher than that of yolk diameter of frizzle eggs stored at room temperature. Yolk diameter for naked neck, frizzle and normal feather eggs with vegetable oil application stored at room temperature was significantly ($p<0.05$) lower than that of those eggs without vegetable oil application stored at room temperature. Increased in yolk diameter values of eggs without oil application at room temperature could be due to the enlargement of yolk size by absorption of more moisture from albumen, which could also result in yolk deterioration.

4.1. INTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY STORAGE DURATION X STORAGE TEMPERATURE X OIL APPLICATION

Table 4.1 shows results of internal egg quality traits as influenced by interaction of storage duration x storage temperature x oil application on some egg quality traits. Beside yolk diameter and yolk height there were no significant interaction ($p>0.05$) between storage

duration x storage temperature x oil application in the internal egg quality characteristics studied.

Egg stored with vegetable oil application at room temperature significantly ($p<0.05$) increase in yolk diameter values from day 7 to day 28 but lower than the ones without vegetable oil application under room temperature. Eggs coated with and without vegetable oil stored in a refrigerator were significantly lower in yolk diameter values from 7 days to 28 days. Eggs with vegetable oil application and the ones without vegetable oil application stored in a refrigerator recorded significantly ($p<0.05$) similar yolk diameter values from 7 days to 28 days. The eggs without vegetable oil application stored under room temperature also recorded significantly higher yolk diameter values as compared to those eggs without oil application in a refrigerator with regard to the storage period of 7 days to 28 days. This could be attributed to the fact that eggs coated with oil in a refrigerator showing lower yolk diameter at earlier storage period indicates a better yolk quality during storage in that increase in yolk diameter signifies yolk deterioration.

Eggs coated with vegetable oil stored under room temperature (Table 4.1) from 7 days to 28 days showed significantly higher ($p<0.05$) yolk height values than those eggs without vegetable oil application stored under room temperature from 7 days to 28 days. Eggs stored with vegetable oil application in a refrigerator from 7 days to 28 days also recorded higher yolk height values ($p<0.05$) than those eggs in a refrigerator within 7 days to 28 days without vegetable oil application. Eggs stored in a refrigerator with and without vegetable oil application from 7 days to 28 days recorded higher ($p<0.05$) yolk height values than those eggs stored with and without vegetable oil application under room temperature from 7 days to 28 days period. This finding corroborates with that of Scott and Silverside (2000), and Samli *et al*. (2005) who observed that decrease in yolk height with regards to increase in temperature and length of storage time. Mountney, (1976) observed that it was for the reason

that losses of moisture which cause Mucin fiber to gives the albumen and yolks their gel- like texture and structure. And therefore the albumen and yolk becomes watery in the absent of oil application which prevents the evaporation of moisture from the eggs as a result of increase in storage temperature and length of storage time.

Table 4.1. Internal quality of table eggs as influenced by phenotype, storage duration, storage temperature, oiling and their interactions

	Albumen height mm	Albumen weight G	Haugh unit %	Yolk colour	Yolk diameter cm	Yolk height mm	Yolk weight g
Phenotype							
Naked-neck	4.52	33.74	60.36	4.94[a]	4.21	13.38	17.37[b]
Frizzle	4.52	33.69	60.47	4.52[b]	4.23	12.88	17.48[a]
Normal	4.43	32.30	59.92	4.93[a]	4.22	13.18	17.15[c]
SEM	0.071	0.295	0.737	0.098	0.019	0.013	0.098
Storage duration							
0	4.82[a]	34.57[a]	62.25[a]	4.99	4.05[c]	14.62[a]	17.36
7	4.49[b]	34.28[a]	60.94[b]	4.80	4.19[c]	13.15[a]	17.33
14	4.44[b]	33.75[b]	59.95[c]	4.83	4.23[b]	12.91[c]	17.25
21	4.40[b]	32.58[c]	59.80[c]	4.60	4.25[b]	12.93[c]	17.31
28	4.31[c]	32.70[c]	58.30[d]	4.76	4.41[a]	12.13[d]	17.38
SEM	0.084	0.354	0.873	0.116	0.022	0.015	0.112
Storage temperature							
Refrigeration	5.21[a]	34.22[a]	68.27[a]	5.07[a]	4.00[b]	15.13[a]	17.16[b]
Room Temp	3.77[b]	32.93[b]	52.32[b]	4.52[b]	4.46[a]	11.15[b]	17.51[a]
SEM	0.247	0.059	0.617	0.082	0.015	0.144	0.079
Oiling							
Vegetable oil	4.79[a]	33.60[a]	63.77[a]	4.89[a]	4.08[b]	14.08[a]	17.44[a]
No oiling	3.85[b]	32.86[b]	54.00[b]	4.55[b]	4.39[a]	11.75[b]	17.15[b]
SEM	0.059	0.247	0.617	0.116	0.015	0.144	0.079
Source of variation	**P Value**						
Phenotype	0.544	0.512	0.855	0.003	0.822	0.116	0.042
Storage duration	<0.001	<0.001	0.005	0.216	<0. 001	<0.001	0.938
Storage temperature	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.008
Oiling	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Phenotype X Storage duration	0.994	0.384	0.505	0.986	0.099	0.112	0.008
Phenotype X Storage temperature	0.937	0.408	0.945	0.936	0.958	0.715	0.856
Phenotype X Oiling	0.467	0.467	0.580	0.034	0.397	0.583	0.568
Storage duration X Storage temperature	0.052	<0.001	0.035	0.623	<0.001	<0.001	0.003
Storage duration X Oiling	0.830	0.493	0.830	0.643	1.001	<0.001	0.126
Storage temperature X Oil application	0.017	0.696	<0.001	0.144	<0.001	<0.001	0.004
Phenotype X Storage duration X Oiling	0.183	0.018	0.308	0.657	0.375	0.010	0.488
Phenotype X Storage duration X Storage temperature	0.077	0.140	0.111	0.423	0.506	0.020	0.173
Phenotype X Storage Temp X Oiling	0.300	0.850	0.350	0.670	0.040	0.561	0.402
Storage duration X Storage Temp X Oiling	0.043	0.824	0.008	0.655	<0.001	<0.001	0.008

[a,b,c:] *Means with different superscripts within the same row indicate a significant difference (P<0.05), SEM; Standard Error of the Means. P-value: Probability Value*

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE, STORAGE DURATION, STORAGE TEMPERATURE, OILING AND THEIR INTERACTIONS

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE

The effects of phenotype on external egg quality of table eggs are presented in Table 4.2. There were no significant differences ($p>0.05$) among various phenotypes in relation to shell weight, egg length, egg weight, egg width. The absence of significant differences for these parameters may be attributed to the result of the birds coming from common descent even though they appear phenotypically different with respect to their feather structure and distribution. This result agrees with the findings of Rajkumar *et al.* (2009) who observed no significant differences in shell weight, egg weight (28 weeks old) for *NaNa*, *Nana*, and *nana* genotypes in India. Udoh *et al*. (2012) also reported no significant difference ($p>0.05$) among three local genotypes in terms of shell thickness in Nigeria.

The naked neck recorded significantly ($P<0.05$) higher values for shell thickness (0.31mm) than the frizzle and the normal feathered (Table 4.2). Naked neck showing higher shell thickness value could attribute to the result of their feed intake and feed conversion ratio. As the naked neck take in more feed, calcium from the feed is being converted into the egg shell thereby making their shell thicker than the other birds. However, the frizzle and the normal feathered birds showed no significant difference ($p>0.05$) in terms of shell thickness. The current result for naked neck was similar to that of Nwachukwu *et al*. (2006), who also recorded shell thickness between 0.30 mm to 0.34 mm in naked neck, frizzle and normal feathered birds. Yakubu *et al*. (2008) observed 0.38 mm of shell thickness in naked neck chickens from Nigeria which was higher than the values realized in the present study (0.31mm). Egahi *et al*. (2013) also reported shell thickness of 0.33mm in naked neck,

0.36mm in frizzle, and 0.32mm in normal feathered birds. Udoh *et al*. (2012) and Egahi *et al*. (2013) reported no significant difference in thickness between the naked neck, frizzle and normal feathered birds. Rajkumar *et al*. (2009), moreover reported no significant difference ($p<0.05$) in shell thickness between the naked neck and their normal feathered counterparts.

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY STORAGE DURATION

The effect of storage duration on the external quality of table eggs is presented in Table 4.2. Storage duration significantly ($p<0.05$) affected shell thickness, shell weight, egg weight and egg width.

Shell thickness value (Table 4.2) was lower ($p<0.05$) for eggs stored for 28 days compared to all the other storage durations, but day 0 was higher than days 21, 28 and similar to days 7 and 14 in shell thickness values. This could be due to the longer storage time, as the external cover of the egg shell gradually wears away making the shell light. It is however in disagreement with the findings of Akinola and Ibe (2014) who observed a higher value for shell thickness in 28 days storage. Tebesi *et al*. (2012) also recorded higher shell thickness in 14 days than 7 days.

Shell weight (Table 4.2) recorded significantly higher ($p<0.05$) value for day 0 (6.16g) than all the other storage periods. But the value for day 7 was higher ($p<0.05$) than the values for days 14, 21 and 28. The higher shell weight for day 0 (6.16g) and lower shell weight for all the other storage periods could be due to the fact that the shell surface may wear away as eggs are stored for a longer period of time making eggs shells lighter due to increase in dryness of the shell. Akinola and Ibe (2014) also reported similar shell weights for storage duration of day 21 and day 28. Samli *et al*. (2005) observed that shell weight significantly ($P<0.001$) decreased with increased in storage time.

Day 0 (Table 4.2) recorded a significantly higher ($p<0.05$) egg weight (63.22g) than day 7 and the other storage periods; it was followed by day 14, which was also significantly higher than day 21 and day 28. There were no significant differences ($P<0.05$) in egg weight for day 21 and day 28. Akinola and Ibe (2014) recorded higher egg weights for day 7 and day 14 during storage. Raji *et al*. (2009) also recorded similar findings with day 0 showing higher egg weight than day 7 and the rest of the storage time. Dudusola (2009) reported that egg weight loss might be due to loss of carbon dioxide, ammonia, nitrogen, hydrogen sulphide gas and water from the eggs as a result of longer storage period. Samli *et al*. (2005) reported that egg weight loss significantly increased at 21^{o}C to 0.65 and 1.03g at 5 and 10 days of storage time.

Day 0, 7 and day 14 (Table 4.2) were similar in terms of egg length and egg width, and was significantly higher than day 21 and day 28. Reduction in eggs size could be attributed to evaporation of moisture from the eggs as a result of longer storage period. The current study contradicts that of Raji *et al*. (2009) who recorded higher egg length for day 7 and day 28 than day 14 and day 21. Tebesi *et al*. (2012) reported higher mean egg length for day 14 than for day 7. Akinola and Ibe (2014) observed a higher mean egg length for day 7 than for the other storage length.

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY STORAGE TEMPERATURE

Results of the influence of storage temperature on external egg quality is presented in Table 4.2. Shell weight, shell thickness, egg weight, egg length and egg width were not significantly ($p>0.05$) different between the two storage temperatures. Absence of the significant differences for these egg quality traits could be attributed to the fact that storage temperature has no influence on them. The nonappearance of significant difference in egg weight between the two storage temperatures was not into agreement with the findings of

Raji *et al*. (2009) who observed higher egg weight for eggs stored in the refrigerator than those stored under room temperature. ACIAR (1998) reported that the higher weight for eggs stored in a refrigerator might probably be the result of less moisture loss from the eggs. Dudusola (2009) reported that egg weight declined with an increase in length of storage. He further reported that the loss of moisture from stored eggs might also cause the loss of carbon dioxide, ammonia, nitrogen, hydrogen sulphide gas and water from the eggs during storage. The absence of significant difference in egg width and length contradict the findings of Raji *et al*. (2009) who recorded ($p<0.05$) higher values for the width and length of eggs stored in a refrigerator than the ones stored under room temperature.

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY OIL DURING STORAGE

The effect of the application of vegetable oil on external egg quality traits is presented in Table 4.2. There were significant differences ($p<0.05$) between eggs coated with vegetable oil and those that were not coated with vegetable oil for all the external quality traits studied except shell weight, egg length and egg width. Raji *et al*. (2009) observed that egg length and egg width were not significantly affected by oil during storage.

Eggs coated with vegetable oil (Table 4.2) showed higher shell thickness values ($p<0.05$) than the ones not coated with vegetable oil. Raji *et al.* (2009) observed higher shell thickness values for eggs coated with oil during storage.

Eggs coated with vegetable oil were significantly heavier ($p<0.05$) (61.50g) as compared with those that were not coated with vegetable oil (60.40g) during storage (Table 4.1). ACIAR (1998) reported that eggs with oil application recording lower egg weight loss ($P<0.05$) would perhaps be due to less moisture loss from the eggs. Samli *et al*. (2005) observed that

eggs stored under high temperature (29^{o}C) had a higher weight loss than those stored after oil application.

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE X STORAGE DURATION

The results on the influence of phenotype x storage duration on external egg quality traits are presented in Table 4.2. There was no significant phenotype x storage duration interaction for all the external egg quality characteristics studied. The no significant in all the external egg quality trait attributes to the fact that phenotype x storage duration interaction did not affect any of these external quality traits in Table 4.2.

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE X STORAGE TEMPERATURE

The effects of phenotype x storage temperature on egg quality of table eggs are presented in Table 4.2. There were no significant phenotype x storage temperature interactions for all the external egg quality characteristics studied.

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE X OIL APPLICATION

Table 4.2 shows results of the influence of phenotype x oil application on egg quality characteristics of table eggs. The results in Table 4.2 shows no significant ($p<0.05$) phenotype x oil application interactions on all the egg quality parameters studied.

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY STORAGE DURATION AND STORAGE TEMPERATURE

The effects of storage duration and storage temperature on external egg quality characteristics are presented in Table 4.2. The results indicate that shell thickness, shell weight, egg weight,

egg length, egg width, showed no significant difference ($p<0.05$) in terms of the interaction of storage duration x storage temperature.

4.2. EXTERNAL EGG QUALITY TABLE EGGS AS INFLUENCED BY STORAGE DURATION X OIL APPLICATION

Table 4.2 shows results of the influence of storage duration x oil application on external egg quality characteristics. The results showed no significant interactions ($p>0.05$) between storage duration x oil application interaction on egg quality in terms of shell weight, egg length, egg weight and egg width. However, there were significant ($p<0.05$) storage duration x oil interactions in terms of shell thickness.

There was a significant deterioration in the thickness (Table 4.6) of egg shells not coated with oil as storage duration increased. The current result presented in Table 4.6 for shell thickness is similar to that of Akinola and Ibe (2014) who observed lower shell thickness values for eggs stored without oil application at a longer storage time. Tebesi *et al*. (2012) also observed lower shell thickness value for uncoated eggs with oil during longer storage time. Raji *et al*. (2009) however observed no significant differences ($p>0.05$) in shell thickness when they applied vegetable oil to stored eggs.

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY STORAGE TEMPERATURE X OIL APPLICATION

Table 4.2 shows results of the interaction of storage temperature x oil application for some external egg quality traits. The results (in Table 4.2) showed no significant storage temperature x oil application interaction in shell thickness, shell weight, egg length, egg width but there were significant ($p<0.05$) temperature x oil interaction effects on egg weight.

Eggs stored with oil application at room temperature showed significantly higher ($p<0.05$) egg weight value (Table 4.6) compared to eggs stored at room temperature without oil

application. Eggs with oil application in a refrigerator also showed higher egg weight value as compared with those eggs stored without oil application in a refrigerator. Oiled eggs at room temperature also showed significantly higher ($p<0.05$) egg weight value than oiled eggs and non-oiled eggs at room temperature and in a refrigerator, while the non-oiled eggs stored at room temperature recorded the lowest egg weight value. This points to the fact that oil has positive effect on egg quality during storage because it prevents moisture loss in the eggs. Dudusola (2009) and Raji *et al*. (2009) also recorded higher egg weight values for oiled eggs than the ones without oil at room temperature.

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE X STORAGE DURATION X OIL APPLICATION

Table 4.2 shows the external egg quality traits as influenced by interaction of phenotype x storage duration x oil application. The results showed no significant phenotype x storage duration x oil application interaction ($p>0.05$) for all the parameters of external egg quality traits studied.

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE X STORAGE DURATION X STORAGE TEMPERATURE

The effect of phenotype x storage duration x storage temperature interaction on external egg quality characteristics is presented in Table 4.2. The result shows that significant ($p>0.05$) phenotype x storage duration x storage temperature interaction was observed for egg weight.

Naked neck eggs stored in a refrigerator for 7 days recorded significantly ($p<0.05$) higher egg weight values (Table 4.10) as compared to those of frizzle eggs and normal feathered birds stored in a refrigerator for 7 days, while normal feather recorded higher eggs weight values than frizzle. Frizzle and naked neck eggs stored under room temperature for 7 days recorded significantly ($p<0.05$) similar egg weight values than the normal feathered birds. Naked neck

and frizzle eggs stored under room temperature for 14 days showed significantly similar egg weight ($p<0.05$) values but higher than normal feathered, while the normal feathered recorded significantly higher egg weight values for eggs stored in a refrigerator than naked neck and frizzle. Egg weight values for frizzle, naked neck and normal feathered stored in a refrigerator for 21 days remained significantly higher ($p<0.05$) than weight of their eggs stored under room temperature for 21 and 28 days. The significant differences in egg weight among the three phenotypes could be due to their influence on storage time and storage temperature.

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY PHENOTYPE X STORAGE TEMPERATURE X OIL APPLICATION

Table 4.2 shows the results of external egg quality influenced by the interaction of phenotype x storage temperature x oil application on some egg quality traits. The results in Table 4.2 showed no significant ($p>0.05$) phenotype x storage temperature x oil application interaction in all the external egg quality characteristics studied.

4.2. EXTERNAL QUALITY OF TABLE EGGS AS INFLUENCED BY STORAGE DURATION X STORAGE TEMPERATURE X OIL APPLICATION

Table 4.2 shows results of external egg quality traits as influenced by interaction of storage duration x storage temperature x oil application on some egg quality traits. There were no significant interaction ($p>0.05$) between storage duration x storage temperature x oil application in all the external egg quality characteristics studied. This indicates the fact that these three storage methods did not affect the external egg quality traits studied.

Table 4.2. External quality of table eggs as influenced by phenotype, storage duration, storage temperature, oiling and their interactions

	Shell thickness mm	Shell weight g	Egg weight g	Egg length cm	Egg width cm
Phenotype					
Naked-neck	0.30[a]	6.01[a]	61.46	5.90[a]	4.32[a]
Frizzle	0.25[b]	6.09[a]	61.21	5.81[b]	4.33[a]
Normal	0.22[b]	5.95[b]	60.95	5.80[b]	4.28[b]
SEM	0.004	0.042	0.333	0.016	0.010
Storage duration					
0	0.27[a]	6.16[a]	63.21[a]	5.95[a]	4.37[a]
7	0.27[a]	6.02[a]	61.45[b]	5.88[a]	4.31[a]
14	0.27[a]	5.96[b]	61.34[b]	5.87[a]	4.31[a]
21	0.26[a]	5.96[b]	60.04[c]	5.83[b]	4.28[b]
28	0.23[b]	5.99[b]	59.98[c]	5.85[b]	4.28[b]
SEM	0.005	0.049	0.395	0.019	0.012
Storage Temperature					
Refrigeration	0.26	6.02	61.45	5.86	4.30
Room Temp	0.25	6.01	60.96	5.86	4.32
SEM	0.004	0.034	0.279	0.013	0.009
Oiling					
Vegetable oil	0.27[a]	6.05	61.50[a]	5.87	4.30
No oiling	0.24[b]	5.98	60.40[b]	5.86	4.31
SEM	0.003	0.035	60.40[b]	0.013	0.009
Source of variation	**P Value**				
Phenotype	<0.001	0.043	0.569	0.035	0.003
Storage duration	<0.001	0.043	<0.001	<0.001	<0.001
Storage temperature	0.901	0.943	0.467	0.326	0.643
Oiling	<0.001	0.176	<0.001	0.709	0.752
Phenotype X Storage duration	0.989	0.702	0.477	0.156	0.550
Phenotype X Storage temperature	0.870	0.876	0.939	0.577	0.045
Phenotype X Oiling	0.910	0.736	0.986	0.069	0.580
Storage duration X Storage Temperature	0.513	0.841	0.401	0.256	0.034
Storage duration X Oiling	0.007	0.386	0.237	0.632	0.590
Storage temperature X Oiling	0.100	0.279	0.031	0.765	0.502
Phenotype X Storage duration X Oiling	0.390	0.500	0.420	0.464	0.886
Phenotype X Storage duration X Storage temperature	0.756	0.763	0.009	0.164	0.142
Phenotype X Storage Temp X Oiling	0.820	0.930	0.460	0.402	0.511
Storage duration X Storage Temp X Oiling	0.453	0.142	0.166	0.685	0.642

[a,b,c:] Means with different superscripts within the same row indicate a significant difference (P<0.05), SEM; Standard Error of the Means. P-value: Probability Value

4.3 EFFECT OF PHENOTYPE ON THE PROXIMATE COMPOSITION OF TABLE EGG ALBUMEN (AS-FED BASIS)

Table 4.13 shows the result of phenotype on proximate composition of egg albumen. There were no significant difference ($p>0.05$) between phenotypes with regard to moisture, nitrogen free extract (NFE), ash, crude fiber and crude protein of the egg albumen except the crude fat content of the albumen of eggs from frizzled hens was significantly lower (0.08%) than the levels observed in eggs laid by normal feathered and naked neck birds.

4.3 EFFECT OF PHENOTYPE ON THE PROXIMATE COMPOSITION OF TABLE EGG YOLK (AS-FED BASIS)

Effect of genotype on the proximate composition of egg yolk is presented in Table 4.13. There were no significant difference ($p>0.05$) between phenotypes with regard to the proximate composition of egg yolk except the ash content. Eggs from frizzle recorded higher levels of ash ($p<0.05$) than those from the naked neck and normal feathered birds.

Table 4.3. Proximate composition on egg albumen and egg yolk as influence by phenotype (As-fed basis)

phenotype	Moisture, %	NFE, %	Ash, %	Ether Extract, %	Crude Fiber, %	Crude Protein %
Egg Albumen						
Naked neck	89.04	5.14	0.27	0.18[a]	0.02	5.35
Frizzle	89.39	4.93	0.19	0.08[b]	0.03	5.38
Normal	88.66	5.49	0.17	0.20[a]	0.02	5.46
SEM	0.27	0.23	0.04	0.01	0.04	0.13
Egg Yolk						
Naked neck	57.06	6.78	1.24[b]	27.08	0.06	7.78
Frizzle	57.00	6.95	1.58[a]	26.86	0.08	7.53
Normal	57.17	6.74	1.16[b]	27.05	0.07	7.81
SEM	0.09	0.18	0.09	0.18	0.03	0.05
P Value						
Source of variation						
Egg albumen	0.18	0.24	0.12	<0.01	0.21	0.83
Egg yolk	0.40	0.70	0.01	0.67	0.86	0.20

[a,b:] Means with different superscripts within the same column indicate a significant difference ($p<0.05$). SEM; Standard Error of Means, P-value; Probability Value, NFE; Nitrogen Free Extractl

4.4 EFFECT OF PHENOTYPE ON THE AMINO ACID PROFILE OF TABLE EGG ALBUMEN

Table 4.4 shows the effect of phenotypes on the amino acids profile of the egg albumen (egg white). There were no significant differences ($p>0.05$) between the naked neck, frizzle and normal feathered birds with regard to amino acid profile of the egg albumen (egg white). The absence of significant differences between frizzle, naked neck and normal feathered birds with regard to amino acid profile might have been due to the fact that the birds were of common descent, fed with the same diet and raised under the same environmental conditions.

Table 4.4: The Effect of Phenotype on the Amino Acid Profile of the Egg White (Albumen)

	Phenotype				
	Naked neck	Frizzle	Normal	SEM	P-value
ALA, %	0.59	0.59	0.59	0.01	0.95
ARG, %	0.43	0.44	0.45	0.01	0.41
ASP, %	1.02	1.03	1.03	0.01	0.78
CYS, %	0.15	0.14	0.15	0.04	0.58
GLU, %	1.29	1.31	1.32	0.02	0.50
GLY, %	0.35	0.35	0.35	0.03	0.90
HIS, %	0.24	0.24	0.25	0.03	0.76
ILE, %	0.50	0.50	0.50	0.01	0.86
LEU, %	0.82	0.84	0.84	0.01	0.92
LYS, %	0.54	0.53	0.56	0.01	0.38
MET, %	0.31	0.31	0.31	0.06	0.94
MET_CYS, %	0.45	0.45	0.46	0.06	0.57
PHE , %	0.57	0.59	0.59	0.08	0.82
PRO, %	0.34	0.35	0.35	0.04	0.32
SER, %	0.64	0.64	0.65	0.08	0.62
THR, %	0.43	0.42	0.43	0.03	0.75
VAL, %	0.67	0.67	0.67	0.01	0.90

SEM; Standard Error of Means, P-value; Probability Value, ALA; Alanine, ARG; Arginine, ASP; Aspartic acid, CYS; Cystine, GLU; Glutamic acid, GLY; Glycine, HIS; Histidine, ILE; Isoleucine, LEU; Leucine, LYS; Lysine, MET; Methionine, MET_CYS; Methionine + Cystine, PHE; Phenylalanine, PRO; Proline, SER; Serine, THR; Threonine, VAL; Valine.

4.5. EFFECT OF PHENOTYPE ON AMINO ACID OF THE CRUDE PROTEIN IN EGG WHITE (ALBUMEN)

Table 4.5 shows the effect of phenotypes on the amino acid profile of the crude protein in the egg albumen (egg white). There were no significant differences ($p>0.05$) between phenotypes in terms of amino acid in crude protein percent of egg albumen (egg white).

Table 4.5: The Effect of Phenotype on Amino acid profile of the Crude Protein in the Egg Albumen

	Phenotype				
	Naked neck	Frizzle	Normal	SEM	P-value
ALA, %	0.77	0.75	0.75	0.01	0.23
ARG, %	0.56	0.56	0.57	0.01	0.72
ASP, %	1.33	1.31	1.31	0.01	0.08
CYS, %	0.19	0.18	0.18	0.01	0.66
GLU, %	1.68	1.67	1.68	0.01	0.48
GLY, %	0.46	0.46	0.45	0.01	0.45
HIS, %	0.32	0.31	0.31	0.03	0.40
ILE, %	0.65	0.64	0.63	0.01	0.63
LEU, %	1.07	1.07	1.06	0.01	0.24
LYS, %	0.70	0.68	0.71	0.01	0.39
MET, %	0.40	0.39	0.39	0.01	0.48
MET_CYS, %	0.59	0.57	0.58	0.01	0.31
PHE, %	0.76	0.75	0.75	0.01	0.39
PRO, %	0.45	0.43	0.45	0.03	0.19
SER, %	0.84	0.82	0.83	0.01	0.39
THR, %	0.55	0.55	0.55	0.03	0.08
VAL, %	0.87	0.86	0.85	0.01	0.47
CP %	12.9	12.00	12.05	0.07	0.12

SEM; Standard Error of Means, P-value; Probability Value, ALA; Alanine, ARG; Arginine, ASP; Aspartic acid, CP; Cruel Protein, CYS; Cystine, GLU; Glutamic acid, GLY; Glycine, HIS; Histidine, ILE; Isoleucine, LEU; Leucine, LYS; Lysine, MET; Methionine, MET_CYS; Methionine + Cystine, PHE; Phenylalanine, PRO; Proline, SER; Serine, THR; Threonine, VAL; Valine.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSIONS

The following conclusions were made based on the result of this study:

1. Naked neck and frizzle genes had positive influence on egg quality traits.
2. Shorter storage duration (7 days to 14 days) had positive influence on egg quality during storage.
3. Eggs stored at low temperatures ($5^{o}C$) and in a refrigerator showed positive results on egg quality.
4. Eggs coated with vegetable oil also showed better egg quality during storage.
5. Naked neck recorded heavier egg weight than frizzle and normal feathered in their interactions with storage duration and temperature.
6. Refrigerator and vegetable oil showed better yolk quality in their interactions with storage duration.

5.2 RECOMMENDATIONS

1 There is a need to produce more frizzle and naked neck birds in the tropics for better egg quality.

2 Storage duration (time) for eggs must be limited to at most 14 days (2 weeks) in order to maintain its quality for consumption.

3 Eggs should be coated with vegetable oil during storage in order to maintain quality and shelf-life.

4 And that refrigeration would be most appropriate egg storage method under hot and humid environmental conditions.

REFERENCE

Abdel-Rahman, A. (2000). Effect of naked neck gene and housing system on egg production performance of Sharkasi chickens under subtropical conditions. *Egyptian Poultry Science Journal.* 20, (4): 905-926.

ACIAR. (1998). Measurements and maintenance of duck and hen egg quality in Vietnam. Australian Centre for International Agricultural Research. Research note RN 23 12/99.

Adedeji, O. S., Farinu, G. O., Olayeni, T. B., Ameen, S. A. and Babatunde, G. M. (2006). Performance of egg quality parameters of laying hens fed with different dietary inclusion levels of bitter kola (Garcinia Kola). Res. J. Poult. Sci. 2(4): 75-77.

Adomako, A. (2009). Local domestic chickens: their potential and improvement. A Thesis submitted to the Department of Animal Science, Kwame Nkrumah University of Science and Technology for the Degree of Doctor of Philosophy; Pp. 172

Adomako, K., Hagan J.K. and Olympio O.S. (2009). Potentials of indigenous naked neck and frizzle birds in the Ashanti region of Ghana. Proceedings of the sixteenth Biennial Conference of the Ghana Society of Animal Production (GASP). Pp 177-180.

Adomako, K., Hagan, J. K. and Olympio O. S. (2010). Egg production performance of first and filial generation naked neck (NaNa, Nana) and normal feathered (nana) birds of a cross between indigenous naked neck (NaNa, Nana) males and exotic commercial females (nana), Livestock Research for Rural Development 22 (12) Agricultural Station, the University of Connecticut.

Akinola, L.A. and Ibe, G.C. (2014). Effect of Colour, Source and Storage on Quality of Table Eggs in Port Harcourt Metropolis, Rivers State, Nigeria Journal of Research in Agriculture and Animal Science Volume 2 ~ Issue 11 pp:01-06 ISSN(Online) : 2321-9459.

Badubi, S.S., Rakereng, M. and Marumo, M.. (2006). Morphological characteristics and feed resources available for indigenous chickens in Botswana. *Livest. Res. Rural Dev*. 18(1),

Bordas, A., Monnet, L.E. and Mérat, P. (1980). Gene coun, performances et efficacite alimentaire selon la temperature chez la poule. *Ann. Genetics Selection animal*, 12 (4), 343-361

Butcher, G. D. and Miles, R. D., 2003a. Concepts of Eggshell Quality. University of Florida. http://edis.ifas.ufl.edu/pdffiles/VM/VM01300.pdf. Retrieved on 27 February 2016

Butcher, G. D. and Miles, R. D., 2003b. Factors causing poor pigmentation of brown shelled eggs. University of Florida. http://edis.ifas.ufl.edu/pdffiles/VM/VM04700.pdf. Retrieved on 27 February 2016

Cahaner A., Deeb, N. and Gutman, M. (1993). Effect of the plumage reducing naked neck (Na) gene on the performance of fast growing broilers at normal and high ambient temperature. *Poultry Science*, 72:767-775.

Chan Siang N.G., Wu P., Foley J., Foley A., McDonald M-L (2012) The Chicken Frizzle Feather Is Due to an a-Keratin (KRT75) Mutation That Causes a Defective Rachis. PLoS Genet 8(7): e1002748. doi:10.1371/journal.pgen.1002748

Chang C.H., Jiang T.X., Lin C.M., Burrus L.W., Chuong C.M. (2004) Distinct Wnt members regulate the hierarchical morphogenesis of skin regions (spinal tract) and individual feathers. Mech Dev 121: 157–171.

Chatterjee, R.N., Rai, R.B., Kundu, A., Senani S. and Sundar J. (2007). Egg quality traits in indigenous breeds of chicken of Andaman. Ind. Vet. J., 84. 206-208.

Chuong C.M. (1993). The making of a feather: homeoproteins, retinoids and adhesion molecules. Bioassays 15: 513–521.

Dudusola I.O. (2009). Effects of Storage Methods and Length of Storage on some Quality Parameters of Japanese quail Eggs. Tropicultura, 27, 1, 45-4.

EdInformatics.com (2013): The anatomy of chicken egg. www.Edinformatics.com (Accessed 10 June 2016).

Egahi, J.O., Dim, N.I. and Momoh, O.M. (2013). The effect of plumage modifier genes on egg quality indices of the Nigerian local chicken. Journal of Agriculture and Veterinary Science, 2 (2): 04-06.

El-Safty, S.A., Ali U.M. and Fathi M.M. (2006). Immunological parameters and laying performance of naked neck and normally feathered genotypes of chickens under winter conditions of Egypt. *International Journal of Poultry Science*, 5 (8): 780-785.

Farooq M.K., Aneela F.R., Durrani A.K., Muqarrab N.C., Khurshid A. (2001a**).** Egg and shell weight, hatching and production performance of Japanese broiler Quails. Sarhad J. Agric., 17: 289-293.

Farooq M.K., Durrani A.K., Aleem N., Chand N., Muqarrab N.C. (2001b). Egg traits and hatching performance of Desi, Fayoumi and Rhode Island Red Chicken. Pak. J. Bio. Sci. 4(7): 909-911

Fathi, M. M., El-Attar, A. H., Ali, U. M. and Nazmi, A. (2008)**.** Effect of the naked neck gene on carcass composition and immune competence in chicken. *British Poultry Science*, 49 (2): 103 – 110

Fayeye, T. R., Adeshiyan, A. B and Olugbami, A. A. (2005). Egg traits, hatchability and early growth performance of the Fulani- ecotype Livestock Research for Rural Development. 17 (8): 1-7

Garcês, A., Casey., N.H. and Horst P. (2001). Productive performance of naked neck, frizzle and dwarf laying hens under various natural climates and two nutritional treatments. South Africa Journal of Animal Science, 31(3).

Grobas, S., Mendez, J., Lazaro, R., de Blas, C. & Mateos, G.G., (2001). Influence of source and percentage of fat added to diet on performance and fatty acids composition of egg yolks of two strains of laying hens. Poult. Sci. 80: 1171-1179.

Güçlü1, B.K., Uyanık, F. and İşcan K.M. (2008). Effects of dietary oil sources on egg quality, fatty acid composition of eggs and blood lipids in laying quail. South African Journal of Animal Science 2008, 38 (2).

Haaren-Kiso, A., (1991).The effects of naked neck and frizzle genes on performance and immune-competence of chickens. Ph.D. Thesis, Institute for Animal Production, Technical (Humboldt) University of Berlin.

Hamilton, R.M.G. (1982). Methods and factors that affect the measurement of egg shell quality. Poult. Sci. (61): 2022-2039.

Haney, R. (2008). Amino acids in Egg Whites (amino-acids-egg-whites-2688.htm/). San Diego State University and University of California, San Diego.

Haugh R.R., (1937), The Haugh unit for measuring egg quality. United States Egg Poultry. Mag. 43, 552-555, 572-573.

Heath, J. L. (1977). Chemical and related osmotic changes in egg albumen during storage. Poult. Sci. 56:822–828.

Hesse M, Zimek A, Weber K, Magin T. M. (2004) Comprehensive analysis of keratin gene clusters in humans and rodents. Eur J Cell Biol 83: 19–26.

Horst, P. (1988). Native fowl as reservoir for genomes and major genes with direct and indirect effects on production adaptability, *In Proceedings, 18th World Poultry Congress*, Nagoya, Japan, 4–9 September 1988, p. 105.

Horst, P. (1989). Animal genetic resources and potential for resources development in the tropics with special reference to Malaysia, Malaysia Applied Biology, 16:13-22.

Horst, P. and Mathur, P.K. (1994). Feathering and adaptation to tropical climates. 9th European Poultry Conference, Glasgow, UK, 7-12 Aug. 1994, pp. 79-82. http://edis.ifas.ufl.edu/pdffiles/VM/VM01300.pdf Retrieved on April 11, 2016.

Islam, M. A., Bulbuli, S. M., Seeland, G and Islam, A. B, (2001). Egg quality in different chicken genotypes in summer and winter. Pak. Journal of Biological Science, 4: 1411-1414.

Jin, Y. H., Lee, K. T., Lee, W. I., Han, Y. K. (2011): Effects of storage temperature and time on the quality of eggs from laying hens at peak production. Asian-Aust. J. Anim. Sci. 24, 279-284.

Khan, M.J.A., Khan S.H., Bukhsh A., Abbass M.I. and Javed, M. (2013). Effect of different storage period on egg weight, internal egg quality and hatchability characteristics of Fayumi eggs. Ital. J. Anim. Sci., 12: 51.

Khurshid A.M., Farooq M. K., Durrani A**.** K, Sarbiland N'Chand (2003). Predicting Egg Weight, Shell Weight, Shell Thickness and Hatching Chick Weight of Japanese Quails Using Various Egg Traits as Repressors. Intern. J. Poult. Sci. 2(2): 164-167.

Kitalyi, A. J. (1998). Village chicken production systems in rural Africa: Household food security and gender issues. FAO Animal Production and Health Paper 142, Rome, 1998. Pp 254.

Kul, S. and Seker, I. (2004). Phenotypic correlations between some external and internal egg quality traits in the Japanese quail (Cortunixcortunix Japanica). Int. J. Poultry Science 3: 400 – 405.

Leeson, S. and Caston, L. J. (2003). Vitamin enrichment of eggs. J. Appl. Poult. Res., 12: 24-26.

Li-Chan E.C.Y., Powrie W.D., Nakai S. (1995). The chemistry of eggs and egg products. In: WJ Stadelman, OJ Cotterill (Edn.), Egg Science and Technology, 4th Edn. Food Products Press, NY; pp 105.

Mahrous, M., Galal, A., Fathi, M. M. and Zein El-Dein, A. (2008). Impact of naked neck (Na) and frizzle (F) genes on Growth Performance and Immuno-competence in Chickens. *International Journal of Poultry Science,* 7 (1): 45-54.

Mathur, P. K. (2003). Genotype- environment interactions: Problems associated with selection for increased production. In; Poultry Genetics, Breeding and Biotechnology edited by M.W. Muir and S.E. Aggrey. CABI Publishing, UK, P. 546.

Mérat, P. (1986). Potential usefulness of the Na (Naked Neck) gene in poultry production. World poultry science Journal, 42: 124-142.

Mérat, P. (1990). Major genes in fowls (*Gallus Gallus*): genes other than those affecting size. *Animal Production*, 3: 355-368.

Mou C., Patel F., Gourichon D., Vignoles F., Tzika A., Tato P., Yu L., Burt D.W., Bed'hom B., Tixier-Boichard M., Painter K.J, and Headon D.J (2011). Cryptic patterning of avian skin confers a developmental facility for loss of neck feathering. PLoS Biology 9(3):e1001028.

Mountney G.J. (1976). Poultry production technology. 2nd Edition. AVI publishing company, west port Connecticut. p. 291.

N'Dri A.L., Mignon-Grasteau S., Sellier N., Beaumont C. and Tixier-Boichard M. (2007). Integrations between the naked neck gene, sex, and fluctuating ambient temperature on heat tolerance, growth, body composition, meat quality and sensory analysis of slow growing meat type broilers. *Livestock Science,* 10: 33-45.

Njenga, S.K., P. Sorensen., and P.N. Nyaga (2005). The productive performance of the different phenotypes of indigenous poultry in Coastal Kenya. Master of Science Thesis, Danish Institute of Agriculture Sciences, Tjee, Denmark. Pp 1-93.

Nwachukwu, E. N., Ibe, S. N. and Ejekwu, K. (2006). Short term egg production and egg quality characteristics of main and reciprocal crossbred normal local, naked neck and frizzle chicken X exotic broiler breeder stock in a humid tropical environment. *Journal of Animal and Veterinary Advances*, 5 (7): 547-551.

Ogunwole, O.A., Akinola Y. P., Ojelade, A., Oyewo, M.O., Essien, E.A. (2015). Proximate Composition and Physical Characteristics of Eggs from Laying Chickens Fed Different Proprietary Vitamin-Mineral Premixes Under Two Rearing Systems During Storage. Int. J. of Food Sci and Nutri. Engn. 5(1): 59-67

Oke, U. K. (2011). *Online Journal of Animal and Feed Research 1(3): 92-98 (2011) ISSN 2228-7701*.

Okur A.A. and Akyurek, H. (2009). Effect of storage time, temperature and hen age on egg quality in free- range layer hens. J. Anim. Vet. Adv., 8: 1953-1958.

Oluyemi, J.A. and Roberts, F. A. (2000). Poultry production in worm and wet Climates. 2nd Edn. Spectrum Books, Ibadan, and ISBN13:9789780290979, PP: 190.

Orji B.I., Igboeli C. & Okoye P.T., (1981). The effect of pre-incubation storage on embryonic growth rate, mortality, hatchability and total incubation period of fowl egg. Nig. J. of Agric Sci. 31, 99-103.

Park, Y. S. Yoo, I. J. Jeon, K. H. Kim, H. K. Chang, E. J. and Oh, H.I. (2003). Effects of various Eggshell Treatments on the Egg Quality during storage. Department of Food Science and Technology, Sejong University, Seoul. 143-747, Korea *(Asian-Aust. J. Anim. Sci. Vol. 16, No. 8:1224-1229).*

Patel, K., Makarenkova, H. and Jung, H. S. (1999). The role of long range, local and direct signaling molecules during chick feather bud development involving the BMPs, follistatin and the Eph receptor tyrosine kinase Eph-A4. Mech Dev 86: 51- 62.

Pech-Waffenschmidt, V. (1992). The effect of heat stress conditions on performance, physiology, and blood chemistry of laying hens of different feathering types, and nutritional considerations to improve the heat resistance PhD Dissertation. Agric. TU Berlin Nr. 245.

Peters, S. O., Ikeobi, C. O. N., Ozoje, M. O., Famakinwa, O. A., Oshodi., Y. S. and Adebambu, O. A. (2007). Egg quality of Nigerian local chicken as influenced by some major genes. Nigerian Journal of Animal Production. 34: 25-35.

Raji, A. O., Aliyu, J., Igwebuike, J. U and Chiroma, S. (2009). Effect of storage methods and time on egg quality traits of laying hens in hot dry climate. ARPN Journal of Agriculture and Biological Science 4: 1 – 7.

Rajkumar, U., Sharma, R.P., Rajaravindra, K.S., Niranjan, M., Reddy, B.L.N., Bhattacharya, T.K., and Chatterjee, R.N. (2009). Effect of Genotype and Age on Egg Quality Traits in Naked Neck Chicken under Tropical Climate from India, International Journal of Poultry Science 8 (12): 1151-1155.

Robinson, D. S. (1987). The chemical basis of albumen quality. Pages 171–191 in Egg Quality—Current Problems and Recent Advances. R. G. Wells and C. G. Belyavin, ed. Butterworths, London.

Roush, W.B. (1981). TI 59 calculator program for Haugh unit's calculation. Poultry Science, v.60, p.1086-1088.

Samli, H.E., Agma A. and Senkoylu, N. (2005). Effects of storage temp and temperature on egg quality in old laying hens. J. Appl. Poult. Sci., 14: 548-553.

Scott, T.A. and Silversides, F.G. (2000). The effect of storage and strain of hen on egg quality. Poult. Sci., 79: 1725-1729.

Sharp, P.R. and Powell, C.K. (1930). Decreases in internal quality of hen's egg during the storage as indicated by yolk. Ind. Eng. Chem., 22:9.

Singh, C.V., Kumar, D. and Singh, Y.P. (1996). Potential usefulness of the plumage reducing Naked Neck (Na) gene in poultry production at normal and high ambient temperatures. World Poultry Science Journal. 57:139-156.

Somes, R.G. (1998). International registry of poultry genetic stocks. Storrs Agric. Expt. Staion. Bull. 476.

Spamer, C. O., (1931). Historic methods and present practices of preserving egg in Holland. U.S. Egg Poultry Mag. 37:48-54.

Stadelman, W.J. (1977). Quality identification of shell eggs. In: Egg science and technology; 2nd Edn. AVI Publishing Company Inc. Westport, Connecticut.

Tanabe, H. and Ogawa N. (1979). Survey of the methods for long terms storage of poultry eggs. 17. The effects of washing and coating materials, vegetable oil, mineral oil and sucrose-fatty acid ester emulsion on interior quality of chicken eggs. Japan. Poult. Sci. 16: 190-199.

Tebesi T., Madibela O. R. and Moreki J. C. (2012). Effect of Storage Time on Internal and External Characteristics of Guinea Fowl (Numida meleagris) Eggs. J Anim Sci Adv. 2012, 2(6): 534-542.

The Medstar Georgetown University Hospital Nutritional Database (2009). Nutrition values of egg white vs yolk. (Retrieved on 07 March 2016) http://www.ams.usda.gov/poultry/pdfs/EggGrading%20manual.pdf.

Touchburn, S.P., Guillaume, J. Leclerca, B. and Blum, J.C. (1980). Lipid and energy metabolism in chicks affected by dwarfism (dwf) and naked neck (Na). Poultry Science, 59:2189-2197.

Tumova, E., Zita, L., Hubeny, M., Skrivan, M. and Ledvinka, Z. (2007). The effect of oviposition time and genotype on egg quality characteristics in egg type hens. Czech. J Anim. Sci. 52: 26-30

Udoh U.H., Okon B. and Udoh A.P. (2012). Egg Quality Characteristics, Phenotypic Correlations and Prediction of Egg Weight in Three (Naked Neck, Frizzled Feather and Normal Feathered) Nigerian Local Chickens. International Journal of Poultry Science 11 (11): 696-699, 2012 ISSN 1682-8356.

United States Department of Agriculture - USDA. Egg-grading manual. Washington: Department of Agriculture. (2000). 56p. (Agricultural Marketing Service, 75).

United States Department of Agriculture (USDA) (2008). Food Safety and Inspection Service, Risk assessments of Salmonella Enteritis in shell eggs and Salmonella spp. in egg products. Available from- http://www.fsis.usda.gov/PDF/SE_Risk. Accessed on March 19 2016.

USDA Agricultural Research Service, 2009. USDA National Nutrient Database for Standard Reference, Release 23. URL: http://www.ars.usda.gov/nutrientdata (accessed May 17, 2016).

Washburn, K.W. (1982). Genetic variation in egg composition. In: Poultry Breeding and Genetics pp: 781-804. Crawford R.D. (Ed.), Elsevier Science Publisher, B V, Amsterdam, the Netherlands.

Widelitz R.B., Veltmaat J.M., Mayer J.A., Foley J., Chuong C.M. (2007). Mammary glands and feathers: comparing two skin appendages which help define novel classes during vertebrate evolution. Semen Cell Dev Biol 18: 255–266.

Williams, K. C. (1992). Some factors affecting albumen quality with particular reference to Haugh unit score. World's Poult. Sci. J. 48:5–16.

Xie, L., Hettiarachchy, N. S., Ju, Z. Y., Wang, H., Slavik M. F. and Janes M. E. (2002). Edible film coating to minimize eggshell breakage and reduce post-wash bacterial contamination measured by dye penetration in eggs. J. Food Sci. 67: 280-284.

Yakubu A., Oga O. M. and Barde R. E. (2008). Productivity and Egg Quality Characteristics of Free Range Naked Neck and Normal feathered Nigerian indigenous Chickens. International Journal of Poultry Science, 7 (6): 579-588.

Yoshimura, Y., Barua, A., Heryanto, B., Ohira, H. and Zheng, W. (1997). Reproductive physiology in domestic animals as a basic knowledge to improve poultry production in Asian countries. Journal of International Development and Cooperation, 3: 27-41.

Zein El-Dein, A. (1981). Use of some marker genes in improving rate of growth in chickens. Ph.D. Thesis, Ain Shams University, Egypt.

Zulkifli I., Yamada, Y., Kadijah, W., Vidyadaran, M. K. and Dahlan I. (1992). The effect of sex-linked dwarf, naked neck and frizzle genes on the egg quality traits of laying hens under tropical conditions. *Veterinary Malay Journal*, 4:1, 33-39.

APPENDICES

Appendices for all ANOVAs in the current study cover the external and internal egg quality, proximate composition and nutritional values of egg produced by the naked neck, frizzle and normal feather genotypes used in the research.

APPENDIX 1. ANOVA FOR HAUGH UNIT OF EGG QUALITY; VARIATE: HAUGH_UNIT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	30.8	15.4	0.09	0.914
sd	3	2443.4	814.5	4.72	0.003
st	1	55594.2	55594.2	322.49	<.001
oa	1	20600.2	20600.2	119.50	<.001
genotype.sd	6	1201.3	200.2	1.16	0.325
genotype.st	2	123.8	61.9	0.36	0.698
sd.st	3	1105.0	368.3	2.14	0.094
genotype.oa	2	430.8	215.4	1.25	0.287
sd.oa	3	61.2	20.4	0.12	0.949
st.oa	1	2270.0	2270.0	13.17	<.001
genotype.sd.st	6	1240.6	206.8	1.20	0.304
genotype.sd.oa	6	791.7	132.0	0.77	0.597
genotype.st.oa	2	321.6	160.8	0.93	0.394
sd.st.oa	3	515.4	171.8	1.00	0.394
genotype.sd.st.oa	6	1249.9	208.3	1.21	0.300
Residual	816	140672.7	172.4		
Total	863	228652.7			

APPENDIX 2. ANOVA FOR SHELL THICKNESS; VARIATE: SHELL THICKNESS (CM)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.945301	0.472650	85.27	<.001
sd	3	0.242870	0.080957	14.60	<.001
st	1	0.001157	0.001157	0.21	0.648
oa	1	0.161157	0.161157	29.07	<.001
genotype.sd	6	0.009421	0.001570	0.28	0.945
genotype.st	2	0.006968	0.003484	0.63	0.534
sd.st	3	0.007454	0.002485	0.45	0.719
genotype.oa	2	0.003912	0.001956	0.35	0.703
sd.oa	3	0.055231	0.018410	3.32	0.019
st.oa	1	0.015000	0.015000	2.71	0.100
genotype.sd.st	6	0.010532	0.001755	0.32	0.928
genotype.sd.oa	6	0.023032	0.003839	0.69	0.656
genotype.st.oa	2	0.002153	0.001076	0.19	0.824
sd.st.oa	3	0.005463	0.001821	0.33	0.805
genotype.sd.st.oa	6	0.033495	0.005583	1.01	0.419
Residual	816	4.523333	0.005543		
Total	863	6.046481			

APPENDIX 3. ANOVA FOR SHELL WEIGHT; VARIATE: SHELL_WEIGHT (G)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	2.7942	1.3971	2.61	0.074
sd	3	6.0975	2.0325	3.79	0.010
st	1	0.0617	0.0617	0.12	0.734
oa	1	1.1484	1.1484	2.14	0.144
genotype.sd	6	2.8969	0.4828	0.90	0.493
genotype.st	2	0.6391	0.3195	0.60	0.551
sd.st	3	0.1817	0.0606	0.11	0.952
genotype.oa	2	0.1855	0.0927	0.17	0.841
sd.oa	3	1.0033	0.3344	0.62	0.600
st.oa	1	0.6283	0.6283	1.17	0.279
genotype.sd.st	6	0.9730	0.1622	0.30	0.936
genotype.sd.oa	6	1.7693	0.2949	0.55	0.770
genotype.st.oa	2	0.0836	0.0418	0.08	0.925
sd.st.oa	3	3.0048	1.0016	1.87	0.133
genotype.sd.st.oa	6	0.2880	0.0480	0.09	0.997
Residual	816	437.2561	0.5359		
Total	863	459.0116			

APPENDIX 4. ANOVA FOR ALBUMEN HEIGHT; VARIATE: ALBUMEN HEIGHT (CM)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	1.231	0.616	0.40	0.671
sd	3	31.957	10.652	6.91	<.001
st	1	449.223	449.223	291.48	<.001
oa	1	187.973	187.973	121.97	<.001
genotype.sd	6	11.407	1.901	1.23	0.287
genotype.st	2	1.231	0.616	0.40	0.671
sd.st	3	9.041	3.014	1.96	0.119
genotype.oa	2	1.926	0.963	0.62	0.536
sd.oa	3	0.568	0.189	0.12	0.947
st.oa	1	8.760	8.760	5.68	0.017
genotype.sd.st	6	12.852	2.142	1.39	0.216
genotype.sd.oa	6	9.491	1.582	1.03	0.407
genotype.st.oa	2	3.694	1.847	1.20	0.302
sd.st.oa	3	6.281	2.094	1.36	0.254
genotype.sd.st.oa	6	14.944	2.491	1.62	0.140
Residual	816	1257.611	1.541		
Total	863	2008.193			

APPENDIX 5. ANOVA FOR ALBUMEN WEIGHT VARIATE: ALBUMEN WEIGHT (G)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	51.87	25.93	0.96	0.384
sd	3	785.86	261.95	9.68	<.001
st	1	361.60	361.60	13.36	<.001
oa	1	118.69	118.69	4.39	0.037
genotype.sd	6	37.98	6.33	0.23	0.966
genotype.st	2	104.88	52.44	1.94	0.145
sd.st	3	467.34	155.78	5.76	<.001
genotype.oa	2	48.03	24.01	0.89	0.412
sd.oa	3	37.20	12.40	0.46	0.712
st.oa	1	4.14	4.14	0.15	0.696
genotype.sd.st	6	182.82	30.47	1.13	0.345
genotype.sd.oa	6	314.54	52.42	1.94	0.072
genotype.st.oa	2	8.81	4.40	0.16	0.850
sd.st.oa	3	35.73	11.91	0.44	0.724
genotype.sd.st.oa	6	105.85	17.64	0.65	0.689
Residual	816	22082.83	27.06		
Total	863	24748.18			

APPENDIX 6. ANOVA FOR EGG WEIGHT; VARIATE: EGG WEIGHT (G)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	42.80	21.40	0.62	0.537
sd	3	1615.39	538.46	15.65	<.001
st	1	51.24	51.24	1.49	0.223
oa	1	260.26	260.26	7.56	0.006
genotype.sd	6	254.66	42.44	1.23	0.287
genotype.st	2	26.67	13.33	0.39	0.679
sd.st	3	61.48	20.49	0.60	0.618
genotype.oa	2	5.99	3.00	0.09	0.917
sd.oa	3	97.16	32.39	0.94	0.420
st.oa	1	160.51	160.51	4.67	0.031
genotype.sd.st	6	461.84	76.97	2.24	0.038
genotype.sd.oa	6	131.28	21.88	0.64	0.702
genotype.st.oa	2	54.25	27.12	0.79	0.455
sd.st.oa	3	57.86	19.29	0.56	0.641
genotype.sd.st.oa	6	150.50	25.08	0.73	0.626
Residual	816	28076.27	34.41		
Total	863	31508.16			

APPENDIX 7. ANOVA FOR EGG LENGTH; VARIATE: EGG_LENGTH (CM)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.0041738	0.0020869	2.79	0.062
sd	3	0.0150708	0.0050236	6.71	<.001
st	1	0.0013500	0.0013500	1.80	0.180
oa	1	0.0001042	0.0001042	0.14	0.709
genotype.sd	6	0.0087771	0.0014628	1.96	0.070
genotype.st	2	0.0012549	0.0006274	0.84	0.433
sd.st	3	0.0022231	0.0007410	0.99	0.397
genotype.oa	2	0.0008340	0.0004170	0.56	0.573
sd.oa	3	0.0004523	0.0001508	0.20	0.895
st.oa	1	0.0000667	0.0000667	0.09	0.765
genotype.sd.st	6	0.0062164	0.0010361	1.38	0.218
genotype.sd.oa	6	0.0024262	0.0004044	0.54	0.778
genotype.st.oa	2	0.0013715	0.0006858	0.92	0.400
sd.st.oa	3	0.0023917	0.0007972	1.07	0.363
genotype.sd.st.oa	6	0.0030757	0.0005126	0.69	0.662
Residual	816	0.6105444	0.0007482		
Total	863	0.6603329			

APPENDIX 8. ANOVA FOR EGG WIDTH; VARIATE: EGG_WIDTH (CM)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.0031965	0.0015983	5.40	0.005
sd	3	0.0117597	0.0039199	13.25	<.001
st	1	0.0001852	0.0001852	0.63	0.429
oa	1	0.0000296	0.0000296	0.10	0.752
genotype.sd	6	0.0031840	0.0005307	1.79	0.098
genotype.st	2	0.0021600	0.0010800	3.65	0.026
sd.st	3	0.0018546	0.0006182	2.09	0.100
genotype.oa	2	0.0004183	0.0002091	0.71	0.494
sd.oa	3	0.0001139	0.0000380	0.13	0.943
st.oa	1	0.0001338	0.0001338	0.45	0.502
genotype.sd.st	6	0.0022669	0.0003778	1.28	0.265
genotype.sd.oa	6	0.0004882	0.0000814	0.27	0.949
genotype.st.oa	2	0.0004002	0.0002001	0.68	0.509
sd.st.oa	3	0.0002782	0.0000927	0.31	0.816
genotype.sd.st.oa	6	0.0011488	0.0001915	0.65	0.693
Residual	816	0.2414778	0.0002959		
Total	863	0.2690958			

APPENDIX 9. ANOVA FOR YOLK WEIGHT; VARIATE: YOLK_WEIGHT (G)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	17.604	8.802	3.22	0.041
sd	3	2.164	0.721	0.26	0.852
st	1	26.285	26.285	9.60	0.002
oa	1	17.596	17.596	6.43	0.011
genotype.sd	6	56.957	9.493	3.47	0.002
genotype.st	2	3.608	1.804	0.66	0.518
sd.st	3	31.081	10.360	3.78	0.010
genotype.oa	2	7.062	3.531	1.29	0.276
sd.oa	3	11.249	3.750	1.37	0.251
st.oa	1	22.848	22.848	8.35	0.004
genotype.sd.st	6	17.301	2.883	1.05	0.389
genotype.sd.oa	6	9.297	1.549	0.57	0.758
genotype.st.oa	2	5.090	2.545	0.93	0.395
sd.st.oa	3	14.517	4.839	1.77	0.152
genotype.sd.st.oa	6	30.256	5.043	1.84	0.088
Residual	816	2233.804	2.738		
Total	863	2506.717			

APPENDIX 10. ANOVA FOR YOLK COLOUR; VARIATE: YOLK_COLOUR

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	45.419	22.709	7.46	<.001
sd	3	16.855	5.618	1.84	0.138
st	1	65.010	65.010	21.35	<.001
oa	1	25.010	25.010	8.21	0.004
genotype.sd	6	5.266	0.878	0.29	0.943
genotype.st	2	2.382	1.191	0.39	0.676
sd.st	3	2.753	0.918	0.30	0.824
genotype.oa	2	1.715	0.858	0.28	0.755
sd.oa	3	2.568	0.856	0.28	0.839
st.oa	1	6.510	6.510	2.14	0.144
genotype.sd.st	6	11.285	1.881	0.62	0.716
genotype.sd.oa	6	7.081	1.180	0.39	0.887
genotype.st.oa	2	2.437	1.219	0.40	0.670
sd.st.oa	3	0.605	0.202	0.07	0.978
genotype.sd.st.oa	6	11.600	1.933	0.63	0.703
Residual	816	2485.278	3.046		
Total	863	2691.777			

APPENDIX 11. ANOVA FOR YOLK DIAMETER; VARIATE: YOLK_DIAMETER_(CM)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Genotype	2		0.0002128	0.0001064	0.11	0.897
sd	3		0.1430409	0.0476803	48.72	<.001
st	1		0.4575865	0.4575865	467.59	<.001
oa	1		0.2046252	0.2046252	209.10	<.001
genotype.sd	6		0.0093428	0.0015571	1.59	0.147
genotype.st	2		0.0000735	0.0000368	0.04	0.963
sd.st	3		0.0690266	0.0230089	23.51	<.001
genotype.oa	2		0.0029587	0.0014793	1.51	0.221
sd.oa	3		0.0315416	0.0105139	10.74	<.001
st.oa	1		0.1699177	0.1699177	173.63	<.001
genotype.sd.st	6		0.0028658	0.0004776	0.49	0.818
genotype.sd.oa	6		0.0051895	0.0008649	0.88	0.506
genotype.st.oa	2		0.0064897	0.0032448	3.32	0.037
sd.st.oa	3		0.0165255	0.0055085	5.63	<.001
genotype.sd.st.oa	6		0.0045722	0.0007620	0.78	0.587
Residual	815	(1)	0.7975660	0.0009786		
Total	862	(1)	1.9214241			

APPENDIX 12. ANOVA FOR YOLK HEIGHT; VARIATE: YOLK_HEIGHT_(CM)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.01132	0.00566	0.12	0.890
sd	3	3.53236	1.17745	24.29	<.001
st	1	22.81500	22.81500	470.72	<.001
oa	1	6.79116	6.79116	140.12	<.001
genotype.sd	6	0.62951	0.10492	2.16	0.044
genotype.st	2	0.02632	0.01316	0.27	0.762
sd.st	3	2.90148	0.96716	19.95	<.001
genotype.oa	2	0.20363	0.10182	2.10	0.123
sd.oa	3	1.06162	0.35387	7.30	<.001
st.oa	1	4.92019	4.92019	101.51	<.001
genotype.sd.st	6	0.54081	0.09014	1.86	0.085
genotype.sd.oa	6	0.13775	0.02296	0.47	0.828
genotype.st.oa	2	0.05586	0.02793	0.58	0.562
sd.st.oa	3	0.90407	0.30136	6.22	<.001
genotype.sd.st.oa	6	0.14850	0.02475	0.51	0.801
Residual	816	39.55000	0.04847		
Total	863	84.22958			

APPENDIX 13. ANOVA FOR MOISTURE CONTENT OF EGG ALBUMEN; VARIATE: %_MOISTURE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	2.3692	1.1846	1.83	0.182
Residual	24	15.5057	0.6461		
Total	26	17.8749			

APPENDIX 14. ANOVA FOR NFE OF EGG ALBUMEN; VARIATE: NFE (NITROGEN FREE EXTRA)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	1.4495	0.7248	1.52	0.239
Residual	24	11.4378	0.4766		
Total	26	12.8873			

APPENDIX 15. ANOVA OF ASH CONTENT FOR EGG ALBUMEN; VARIATE: ASH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.06003	0.03001	2.36	0.116
Residual	24	0.30571	0.01274		
Total	26	0.36573			

APPENDIX 16. ANOVA OF FAT CONTENT FOR EGG ALBUMEN; VARIATE: FAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.068822	0.034411	32.90	<.001
Residual	24	0.025105	0.001046		
Total	26	0.093927			

EGG ALBUMEN

APPENDIX 17. ANOVA FOR EGG ALBUMEN FIBER; VARIATE: FIBER

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.0006095	0.0003048	1.68	0.208
Residual	24	0.0043589	0.0001816		
Total	26	0.0049684			

APPENDIX 18. ANOVA FOR PROTEIN IN EGG ALBUMEN; VARIATE: PROTEIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.0537	0.0268	0.19	0.827
Residual	24	3.3696	0.1404		
Total	26	3.4233			

APPENDIX 19. ANOVA FOR MOISTURE IN EGG YOLK; VARIATE: MOISTURE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.12830	0.06415	0.95	0.402
Residual	24	1.62738	0.06781		
Total	26	1.75568			

APPENDIX 20. ANOVA FOR NFE IN EGG YOLK; VARIATE: NFE (NITROGEN FREE EXTRA)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.2263	0.1132	0.36	0.703
Residual	24	7.6009	0.3167		
Total	26	7.8272			

APPENDIX 21. ANOVA FOR ASH CONTENT IN EGG YOLK; VARIATE: ASH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.87345	0.43673	5.56	0.010
Residual	24	1.88453	0.07852		
Total	26	2.75798			

APPENDIX 22. ANOVA FOR FAT IN EGG YOLK; VARIATE: FAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.2462	0.1231	0.40	0.673
Residual	24	7.3507	0.3063		
Total	26	7.5969			

APPENDIX 23. ANOVA FOR FIBER CONTENT IN EGG YOLK; VARIATE: FIBER

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.002991	0.001495	0.15	0.860
Residual	24	0.236922	0.009872		
Total	26	0.239912			

APPENDIX 24. ANOVA FOR PROTEIN CONTENT IN EGG YOLK; VARIATE: PROTEIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	2	0.44069	0.22034	8.46	0.002
Residual	24	0.62544	0.02606		
Total	26	1.06612			

ANALYSIS OF VARIANCE FOR AMINO ACID IN EGG ALBUMEN (WHITE) FOR NAKED NECK, FRIZZLE AND NORMAL FEATHER GENOTYPES

APPENDIX 25. ANOVA FOR ALANINE IN EGG ALBUMEN; VARIATE: ALA (ALANINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.0000237	0.0000118	0.05	0.947
Residual	6	0.0013048	0.0002175		
Total	8	0.0013285			

APPENDIX 26. ANOVA FOR ARGININE IN EGG ALBUMEN; VARIATE: ARG (ARGININE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.0002626	0.0001313	1.04	0.410
Residual	6	0.0007583	0.0001264		
Total	8	0.0010209			

APPENDIX 27. ANOVA FOR ASPARTIC ACID IN EGG ALBUMEN; VARIATE: ASP (ASPARTIC ACID)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.0001057	0.0000529	0.26	0.782
Residual	6	0.0012374	0.0002062		
Total	8	0.0013431			

APPENDIX 28. ANOVA FOR CRUDE PROTEIN IN ALBUMEN; VARIATE: CP (CRUDE PROTEIN)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.09114	0.04557	3.02	0.124
Residual	6	0.09044	0.01507		
Total	8	0.18158			

APPENDIX 29. ANOVA FOR CYSTINE IN EGG ALBUMEN; VARIATE: CYS (CYSTINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.00006764	0.00003382	0.60	0.581
Residual	6	0.00034093	0.00005682		
Total	8	0.00040856			

APPENDIX 30. ANOVA FOR GLUTAMIC ACID IN EGG ALBUMEN; VARIATE: GLU (GLUTAMIC ACID)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.0009853	0.0004927	0.77	0.502
Residual	6	0.0038161	0.0006360		
Total	8	0.0048014			

APPENDIX 31. ANOVA FOR GLYCINE IN EGG ALBUMEN; VARIATE: GLY (GLYCINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.00000554	0.00000277	0.10	0.902
Residual	6	0.00015858	0.00002643		
Total	8	0.00016412			

APPENDIX 32. ANOVA FOR HISTIDINE IN EGG ALBUMEN; VARIATE: HIS (HISTIDINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.00001520	0.00000760	0.28	0.764
Residual	6	0.00016161	0.00002694		
Total	8	0.00017681			

APPENDIX 33. ANOVA FOR ISOLEUCINE IN EGG ALBUMEN; VARIATE: ILE (ISOLEUCINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.0000567	0.0000284	0.16	0.855
Residual	6	0.0010589	0.0001765		
Total	8	0.0011156			

APPENDIX 34. ANOVA FOR LEUCINE IN EGG ALBUMEN; VARIATE: LEU (LEUCINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.0000591	0.0000296	0.08	0.922
Residual	6	0.0021445	0.0003574		
Total	8	0.0022036			

APPENDIX 35. ANOVA FOR LYSINE IN EGG ALBUMEN; VARIATE: LYS (LYSINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.0009000	0.0004500	1.15	0.378
Residual	6	0.0023503	0.0003917		
Total	8	0.0032503			

APPENDIX 36. ANOVA FOR METHIONINE IN EGG ALBUMEN; VARIATE: MET (METHIONINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.00001195	0.00000597	0.06	0.940
Residual	6	0.00056980	0.00009497		
Total	8	0.00058175			

APPENDIX 37. ANOVA FOR METHIONINE + CYSTINE IN EGG ALBUMEN; VARIATE: MET_CYS (METHIONINE + CYSTINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.0001368	0.0000684	0.61	0.573
Residual	6	0.0006710	0.0001118		
Total	8	0.0008078			

APPENDIX 38. ANOVA FOR PHENYLALANINE IN EGG ALBUMEN; VARIATE: PHE (PHENYLALANINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.0000742	0.0000371	0.21	0.816
Residual	6	0.0010615	0.0001769		
Total	8	0.0011357			

APPENDIX 39. ANOVA FOR PROLINE IN EGG ALBUMEN; VARIATE: PRO (PROLINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.00010539	0.00005269	1.39	0.319
Residual	6	0.00022755	0.00003793		
Total	8	0.00033294			

APPENDIX 40. ANOVA FOR SERINE IN EGG ALBUMEN; VARIATE: SER (SERINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.0001813	0.0000906	0.53	0.616
Residual	6	0.0010353	0.0001726		
Total	8	0.0012166			

APPENDIX 41. ANOVA FOR THREONINE IN EGG ALBUMEN; VARIATE: THR (THREONINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.00002130	0.00001065	0.31	0.747
Residual	6	0.00020858	0.00003476		
Total	8	0.00022988			

APPENDIX 42. ANOVA FOR VALINE IN EGG ALBUMEN; VARIATE: VAL (VALINE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GENOTYPE	2	0.0000649	0.0000324	0.12	0.889
Residual	6	0.0016259	0.0002710		
Total	8	0.0016908			