KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF AGRICULTURE AND RENEWABLE NATURAL RESOURCES

FACULTY OF AGRICULTURE

DEPARTMENT OF ANIMAL SCIENCE

TOPIC:

PHENOTYPIC CORRELATION ESTIMATES OF EXTERNAL AND INTERNAL QUALITY TRAITS OF COBB500 BROILER HATCHING EGGS

BY:
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SUPERVISOR:

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APRIL, 2013

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A THESIS SUBMITTED TO THE DEPARTMENT OF ANIMAL SCIENCE, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA IN PARTIAL FULFILMENT OF THE REQUIREMNT FOR THE AWARD OF THE DEGREE OF A MASTER OF SCIENCE ANIMAL SCIENCE

BY:
BERTHA AMANKWAH

SUPERVISOR:

DR. O.S. OLYMPIO

DEDICATION

This project work is dedicated to my beloved husband Mr. Emmanuel Y. A. Amankwah.

ACKNOWLEDGEMENT

To the Almighty God I say thank you. My special thanks go to Darko Farms and Company Limited for partially sponsoring this project as in the provision of a pen with broiler parents, feed and vaccines.

Sincerest gratitude goes to my able and kind supervisor Dr. O. S. Olympio of the Animal Science Department, faculty of Agriculture, KNUST for the invaluable time and effort he devoted to critically scrutinized my work. Appreciation is also expressed to Mr. Ballah of the Department of Physics Laboratory for his assistance in the use of the various instruments for measuring some of the external and internal quality traits of the egg. I also appreciate the selfless assistance offered me by the production manager of the breeding Farm of Darko Farms and Company Limited, Mr. Senyo Kpodo in raising the birds.

I would like to acknowledge my mother Madam Naomi Larkai for her longsuffering and encouragement. Last but not least my profound gratitude goes to my loving husband, Mr. Emmanuel Adu Amankwah a lecturer at the Biochemistry Department, KNUST, for helping in the analysis of the data, financial support and encouragement throughout the project.

ABSTRACT

This study was aimed at determining the internal and external quality traits of the hatching eggs of Cobb 500 broiler breeders as well as the phenotypic correlations between these traits. A total of 330 eggs collected over a period of eleven weeks during the second half of the first laying cycle, were used for this study. The birds were raised in floor pens at a breeding farm of Darko Farms and Company Limited, at Atwima Manyia a suburb of Kumasi in the Ashanti region, Ghana. The values (external quality parameters) obtained for the egg weight, egg width, egg length, shell thickness, shell ratio, shape index and shell weight respectively were 59.37g, 4.35cm, 5.64cm, 0.54mm, 12.4%, 77.6%, 7.35g. The internal quality parameters; albumen height, albumen weight, albumen ratio, Haugh unit, yolk diameter, yolk height, yolk weight, yolk index, and yolk ratio were found respectively as 5.94mm, 32.63g, 54.80% 75.10, 42.11mm, 16.35mm, 19.43g, 38.81% and 32.84%. According to the results obtained in this research, all the internal quality traits of the eggs except the yolk ratio were found to have significant positive correlations with the weight of the egg. These results suggest that it is possible to use egg weight in determining the egg length, egg width, and weight. Both albumen height and yolk height significantly influenced Haugh unit and this implies that these traits could be used to determine the Haugh unit.

DECLARATION

I, Bertha Amankwah declare that this work was done by me under the supervision of Dr. O.S. Olympio. The work has not been published in part or whole elsewhere while references made have appropriately been cited.

Sign………………………………..

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CHAPTER ONE

1.0 INTRODUCTION

Animal protein in sufficient and balanced levels is considered necessary for human health (Uluocak *et al.*, 1995). Among the protein sources, the poultry species have significant place due to the fact that they have short generation interval, high prolificacy, fast growth rate and ease of raising. Poultry products such as meat and eggs are amongst the most nutritious foods and eggs are rated with milk as one of the best balanced protein foods rich in iron (Fe) and vitamins (Oluyemi and Roberts, 2000). The domestic chicken in particular is ranked first compared to other poultry species in the production of table eggs and meat (Sezer, 2007).

The chicken egg is a biological structure intended by nature for reproduction and it provides a complete diet for the developing embryo (Jacobs *et al.*, 2000). Poultry breeding is generally acceptable to people all over the world and provides an excellent source of protein especially for poor rural communities, because it requires little capital, labour and land. Poultry are good converters of feed into useable protein in meat and eggs. The production cost is low relative to other types of livestock and the return on investment is high, thus farmers need just a small amount of capital to start poultry (Ojo , 2000). In a developing country like Ghana, egg is more affordable by the common man than other sources of animal protein and this gives poultry more advantage over other livestock.

The external and internal qualities of eggs in hens have significant effect on hatchability of incubated and fertile eggs as well as the weight and development of chicks (Shanaway, 1987). Egg quality according to Islam *et al*. (2001) affects the reproductive fitness of the parents. Also the external and internal quality traits of the egg are significant in poultry breeding especially for their influence on yield features of future generations, breeding performances and quality and growth of the chicks. Quality traits of eggs determine prices directly in commercial flocks. In egg processing enterprises, the weight of eggshell, albumen and yolk that form the egg as well as their compositions affect the amount and price of the product (Altan *et al*., 1998).

The avian egg serves as a microhabitat in which the embryo develops in preparation for the next phase of its life in the external environment. The content and composition of the egg influence the development of the embryo contained within the egg as well as its hatchling and even the future performance of the flock (Tserveni-Gousi, 1987). Egg weight is an important egg trait which influences egg quality as well as grading (Farooq *et al*., 2001a). It is a parameter which could be determined about the egg without breaking the egg (Wilson and Suarez, 1993; Farooq *et al*., 2001b).

The composition of the egg varies among species. The size of the egg varies within population and to a lesser extent within clutches of birds. One of the main factors influencing egg size is weight of the hen and in poultry body weight is known to be moderately to highly heritable therefore selection of heavier individuals in the population of broiler hens should result in the improvement of size of the egg (Ayorinde and Oke

1995). Du Plessis and Erasmus (1972) reported that larger hens laid larger eggs than those with smaller body weight. The weight of an egg is directly proportional to albumen, yolk and shell that it contains and this varies significantly between strains of hen (Pandey *et al*., 1986). The hen's age also affects the proportion of yolk, albumen and shell produced. According to them, the value of each parameter is closely connected with all the others and the relationship between *variables* is so complex that it is very difficult to evaluate every single weight by itself. Therefore, abnormality in their interactions can affect their physiological function (Pandey *et al*., 1986).

It is an established fact that the external and internal egg quality traits of any particular breed affect the future generations and their performance (Islam *et al*, 2001). In several species large egg size results in increased size of chick, rate of growth and survival. This is because the mass and composition of an egg have considerable effect on the successive development of the embryo and may influence the survival of the neonate. Thus, growth rate of the embryo during incubation varies in direct proportion to the egg mass (Wilson, 1991).

Studies have also shown that with increasing egg mass there is an increase in hatchability although egg size may not appreciably impact on survivability during the first few days of post hatching. Several suggestions have been made as to the relative importance of each egg component in the determination of hatchling quality. It was suggested that the dry component of albumen may be a crucial factor. Albumen, which contains approximately 67% of the protein content of the egg increases in mass more accurately than does the total mass of the egg providing more protein for assimilation into tissues during embryo development (Fayeye *et al*., 2008).

Nutritional enhancement during embryo development might provide chicks from large eggs with increased success during direct competition with their siblings for food (Hurnik *et al*, 1978). In addition to providing nutrients to the developing embryo, the content of the yolk sack remaining at the end of incubation might serve as a nutritional source during the first few days of post hatching. A substantial portion of variation in hatchling mass can be attributed to differing amount of yolk reserve in the hatchlings which assist the survival and activity of the hatchling (Hurnik *et al.*, 1978).

1.1 Justification

The Cobb 500 broiler, just like any broiler chicken is raised purposely for efficient meat production. The broiler breeder lays fertilized eggs, which is a product of males and females from separate genetic lines or breeds. The chicks they produce are hybrids. Broiler industry breeding programs include identifying lines showing maximum crossbred performance for broiler traits including fast growth rate, liveability, improved feed conversion along with selection based on careful measurement of total carcass and breast meat yields (Thiruvenkadan *et al*., 2006).

Genetic improvement in broiler breeder production would help to build sustainable future for the world's broiler industry. For example genetic improvement in Cobb 500 over the last thirty (30) years included a 10% egg production and carcass yield (Hardiman, 2011).

The quality of the newly hatched chick which depends on the quality of the hatching eggs (internal and external egg quality traits) is a major factor in determining its liveability growth and health. Research has shown a highly significant correlation between egg weight and chick weight (Wilson, 1991). Some researchers have found chick weight to be an accurate predictor of final body weight (Proudfoot and Hulan, 1981).

As a result of genetic selection, different strains of laying hens vary significantly in egg characteristics and production (Curtis *et al.,* 1995). However, selection for one characteristic of the hen such as egg weight may affect other characteristics of the egg (Poggenpoel *et al.*, 1996). Therefore genetic selection programmes need to monitor a range of characteristics to ensure that improvement in one trait is not at the expense of other quality traits.

The Cobb500 is among the few broiler breeds used in broiler production in Ghana. Major hatcheries and sales points of day old chicks in Ghana, example Darko Farms and Company Limited, Topman Farms and Afariwa Farms do deal in Cobb500 products. However there has not been any research in the breed especially with regard to the internal quality traits and the external quality traits of the Cobb500 hatching eggs and the phenotypic correlations between the quality traits of the eggs.

Knowledge of the genetic and phenotypic correlations among traits is important in planning the breeding schemes and to predict the potential progress for Cobb500 breeder egg production (Falconer and Mackay, 1996).

Based on the above mentioned reasons, the generalized objectives and specific objectives are as follows:

1. 2 General Objective

To aid in the acceleration of future response to selection of egg quality traits towards efficient and profitable egg production.

1.3 Specific Objectives

1. To estimate average values of external and internal trait of Cobb500 broiler eggs.
2. To determine the phenotypic correlation between the external quality traits of the eggs.
3. To determine the phenotypic correlation between the internal quality traits of the egg.
4. To determine the existence of phenotypic correlations between the external and internal quality traits of the chicken egg.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Egg

The egg of a laying hen is the end product of a complicated series of processes. It is the vehicle for reproduction and also serves as a source of food for humans (Jacob *et al.,* 2000). As a highly complex reproductive cell, it is essentially a tiny center of life. Initial development of the embryo takes place in the blastoderm. The albumen surrounds the yolk and protects this potential life (embryo). It is an elastic, shock-absorbing semi-solid with high water content. Together the yolk and albumen are prepared to sustain life (the life of a growing embryo) for three weeks, in the case of the chicken. The entire mass is surrounded by two membranes and an external covering called shell which provides for an exchange of gases and a mechanical means of conserving food and water supply to the embryo (Jacob *et al.,* 2000).

2 .2 Egg Formation

The first step in the formation of the egg is ovulation of the yolk from the left oviduct. The yolk is captured by the infundibulum where the developing egg remains for about fifteen minutes and it is here that the formation of the perivitelline membrane and chalazae occurs. In breeder birds, fertilization occurs in this region of the oviduct (Solomon, 1991).

The egg then moves into the magnum where it remains for about three hours while the albumen (proteins) is produced. The layer of proteins provides mechanical and bacteria protection for the yolk as well as creating a template for the later formation of the shell membranes and shell. The developing egg then enters the isthmus, which produces the fibre that make up the inner and outer shell membranes (Johnson, 2000).

The egg then enters the shell gland where water and electrolytes enter the albumen for the formation of the mammilary cores, and it is here that the eggshell is formed. The organic matrix of the eggshell consists of the shell membranes, the mammilary cores, the shell matrix and the cuticle. The inorganic portion of the eggshell consists of calcium carbonate (Nys *et al*., 1999; Lavelin *et al*., 2000). Finally, the egg is laid via vagina and cloaca.

The complex nature of the process of formation of the internal components of the egg and the eggshell mean that the quality problems may arise at any of the several stages during the formation of the egg (Jacobs *et al*., 2000).

2.3 Egg Quality

Egg quality is the general term that relates to the various standards imposed on eggs. These standards can be broken down into those used for determining the quality of the eggshell (external egg quality) and those of the interior of the egg. The microbial contamination of the inside of the egg is greatly affected by the ability of the eggshell to stop micro-organisms and bacteria from entering the egg. Those standards that relate to the quality of the interior of the egg are termed as the internal quality trait of the egg and it relates to the functional, aesthetic and microbiological contamination factors of the yolk and albumen (Sabri *et al*., 1999).

2.4 External Quality Traits of the Chicken Egg

The external quality traits of the hen egg consist of the following: The egg weight, width, length and shell characteristics (Olawumi and Ogunlade, 2008). Egg weight is an important egg trait, which influences egg quality as well as grading (Farooq *et al*, 2001b). It is a parameter which could be determined about the egg without having to break the egg (Wilson and Suarez, 1993). The weight of an egg has a direct relation to the weight of the albumen, yolk and shell it contains and this varies significantly with strains (Pandey *et al*., 1986). Egg length, which is also referred to as the height of the egg is the longest portion observed on the external surface. The egg length is also referred to as the long border. Meanwhile, the egg width which is the shortest portion of the egg is referred to as the breadth or the short border and that is where the dense mass of the yolk is situated (Gunlu *et al*., 2003).

2.4.1 Effects of External Egg Quality Traits on Embryo Development and Hatchability

The physical characteristics of the egg play an important role in the process of embryo development and successful hatching. The most influential egg parameters are the egg weight, shell thickness, shell porosity and shape index which is described as maximum breadth to length ratio and the consistency of the contents. The average values of the egg quality traits mostly meet the requirements for embryo development. Both thick shells and firm interiors, which are accepted as being higher than average, due to an increase in egg weight, will result in a more successful hatching of embryos from heavier eggs (Narushin and Romanov, 2002).

Growth rate in broilers have increased through breeding, however the hatchability of the broiler hatching egg has decreased. Attempts to improve hatchability by increasing shell thickness or shell strength often have proven unsuccessful. Since the respiratory system of the developing embryo is influenced by the structure of the eggshell, it is necessary to examine eggshell quality as it relates to hatchability in the broiler breeder through measurement that describes the shell dynamic respiratory quality (Narushin and Romanov, 2002).

2.4.2 Composition of the Eggshell

Most good quality **eggshells** from commercial layers contain approximately 2.2 grams of calcium in the form of calcium carbonate. The average eggshell contains about 0.3% phosphorus and 0.3% magnesium and traces of sodium, potassium, zinc, manganese, iron and copper. If the calcium from the shell is removed, the organic matrix material is left behind. This organic material has calcium binding properties and its organization during shell formation influences the shell strength (Butler *et al.***,** 1972).

2.4.3 Eggshell Structure

The eggshell has been described as a respiratory organ for the developing embryo by regulating water vapour and vital gas exchange. The basic physiological structure of the eggshell includes various components that are potential barriers to the exchange of vital gases and diffusion of water from the egg (Stewart, 1935; Simons, 1971; Freeman and Vince, 1974). A thin inner film is the most interior barrier of the egg, and it is overlaid by the proteinaceous inner and outer shell membranes. Figures 1 and 2 show the arrangement of the film and inner and outer shell membranes in the eggshell.

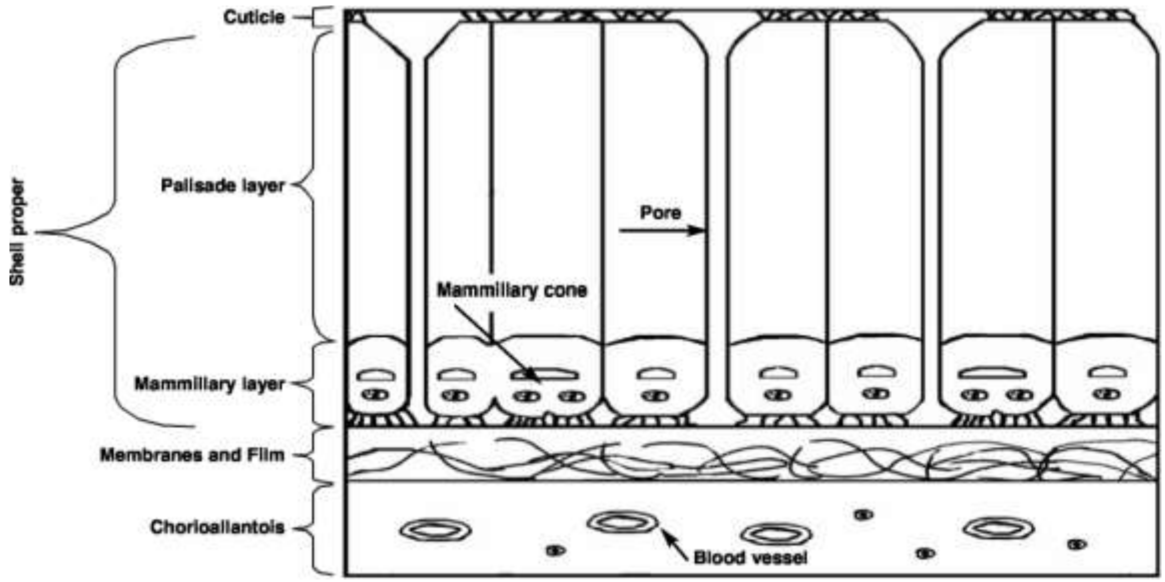

Figure 1.The physiological structure of the eggshell (Parsons, 1982).

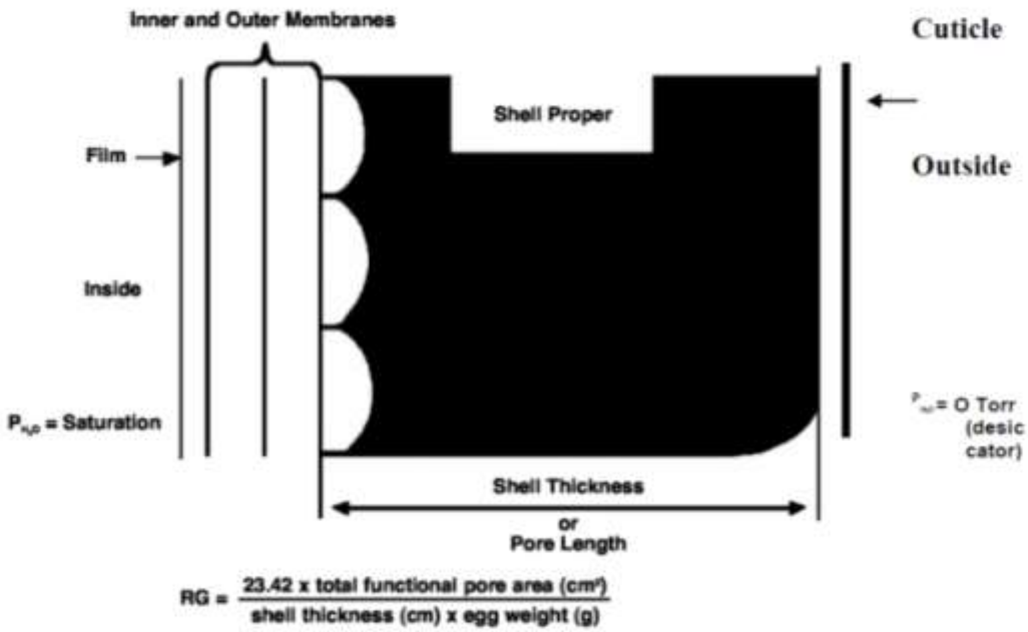

Figure 2. Relative conductance (RG) measurements based on eggshell structural dimensions and the flux of water vapor per unit of tension difference across the shell (Board, 1982).

The thin inner film extends over the outermost surface of the vascularized chlorioalantois; whereas the much thicker outer shell membrane layer possesses mammilary cores, which serve as epitactic centers for calcite crystal formation in the overlaying shell proper (Creger *et al.*, 1976; Stemberger *et al.*, 1977). The thin inner film and inner shell membrane together impede oxygen diffusion to the same extent as does the shell proper; whereas, the shell proper is almost totally responsible as the barrier to both carbon dioxide and water vapour diffusion (Rahn *et al*., 1979).

Calcified mammilary knobs form on the cores, and crystals grow upwards from the knobs and join with adjacent crystals, creating the cones of the mammilary region and crystal columns of the overlaying palisade or spongy layer. Pores in the eggshell proper are formed where the edges of cones or columns fail to meet evenly (Figure 1). These, mammilary core formation and distribution are related to the mechanical strength and respiratory quality of the eggshell (Robinson and King, 1970). The form and distribution of pores may also vary considerably among avian species (Board *et al*., 1977; Tullett, 1984). There is an uneven organic cuticle layer that covers the outer surface of the eggshell. This cuticle is made up of protein with polysaccharide and lipid material (Baker and Balch, 1962; Simkiss, 1968; Simons, 1971). The cuticle may either bridge the outer pore openings or extend down into the pore canals, plugging them (Cooke and Balch, 1970; Board, 1992). The cuticle may also link the Lumina of pore canals to the eggs exterior and, thereby, serve as a pathway for gas diffusion (Board and Scott, 1980).

2.4.4 Factors Affecting Eggshell Quality

2.4.4.1 Hen's age

Research has shown that eggshell quality decreases as the bird grows older (Nys, 1986; Roland *et al*., 1975; Roland, 1979; Roberts and Ball, 2004). Although egg size increases with increasing hen age at the same time as shell weight increases or stays the same, the increase in egg weight is not accompanied by a proportional increase in shell weight so that the ratio of shell weight to egg weight decreases. There is evidence that the inability of the hen to produce an increased amount of eggshell is related to the activity of 25-hydroxy-cholecalciferol-1-hydroxylase, an enzyme involved in calcium homeostasis (Joyner *et al*., 1987; Elaroussi *et al*., 1994). Dietary manipulations that decrease egg size may improve eggshell quality in older hens (Keshavarz, 2003) and also some supplements are effective in improving eggshell quality in older hens (Mabe *et al*., 2003).

2.4.4.2 Moult

The effect of aging on eggshell quality can be reversed to some degree by the process of induced moulting (Ahmed *et al*., 2003; Berry, 2003). Results are variable depending on the nature of severity of the moult and the age of the birds. It was reported by Roland and Brake (1982) that the benefits did not last long in older birds but other researchers have referred to the relatively transient nature of the improvement in shell quality (Lee, 1982; Abu-Serewa and Karunajeewa, 1985; Karunajeewa *et al*., 1989; Al-Batshan *et al*., 1994).

2.4.4.3 Nutrition

Each eggshell contains up to three grams of calcium. Therefore, the diet of the hen must contain adequate calcium in a form that can be utilized efficiently. There is conflicting evidence about the use of particulate calcium although the consensus appears to be that 50-70% of the calcium should be in the form of coarse particles and the remainder in powder form (Nys, 1999). The provision of larger particles (shell grit) which is compatible with automated feeding systems has been shown to have beneficial effects. Some authors recommend a mixture of ground limestone and oyster shell (Richter *et al*., 1999). Inadequate dietary phosphorus may cause demineralization of the skeleton in the laying hen. The ratio of calcium to phosphorus in the diet is important as high levels of phosphorus may interfere with the absorption of calcium from the gut resulting in reduced shell quality (Boorman and Gunaratne, 2001). Calcium and phosphorus requirements appear to be influenced by the age of the birds, amongst other things (Bar *et al*., 2002; Sohail and Roland, 2002). Also environmental conditions have resulted in pressure to minimize levels of phosphorus in the diets, especially in most densely populated countries. The levels of calcium in feed need to be increased during the rearing period, seven to ten days prior to the appearance of the first egg (Roland and Bryant, 1994). However, if additional calcium is not provided early enough, there may be long-term negative effects on calcium metabolism and bone stores of calcium (Nys, 1999; Roland and Bryant, 2000).

Vitamins such as vitamin D are necessary for calcium metabolism and must be included in the diet (Hurwitz, 1987). However, excess vitamin D and its metabolites have not been shown to benefit eggshell quality when normal hens are already consuming adequate vitamin D (Butler *et al.,* 1972). The vitamin D metabolite 25-hydroxyvitamin D3 (which is converted to the biologically active form of vitamin D3 inside the bird) is now commercially available and may prove valuable under some circumstances. Adequate levels of vitamin C are essential for normal good health and may also help to alleviate the effects of stress (Daghir, 1995a). There is also evidence that supplemental vitamin E assists during conditions of heat stress. Low levels of vitamin A may increase the incidence of blood spots, which reduce the internal quality of the egg (Bollengierlee *et al*., 1998).

Water quality may influence eggshell quality. Water containing high levels of electrolytes may have long-term negative effects on eggshell quality (Balnave and Yoselewitz, 1987). However, the imported strains of laying hens do not appear to be susceptible to this effect as are the Australian - bred strain (Chen and Balnave, 2001). The water supplied to birds must also be hygienic to ensure that disease is not transmitted by this route. The temperature of the water provided to laying hen is also important, especially during hot weather. It appears that hens reduce water intake or may even cease to drink, if the water gets too hot. Studies have shown that provision of cool drinking water can improve eggshell quality in heat-stressed hens (Glatz, 1993).

High levels of non-starch polysaccharides in diets increase viscosity of the gut, hold a large amount of water and cause watery droppings. The use of non-starch degrading enzymes has been used for some time in broiler diets to alleviate these problems (Choct and Hughes, 1997). Recently feed enzymes have been added to the diets of laying hens, mainly in an attempt to reduce the incidence of wet droppings and consequent management problems. A study conducted at the University of New England found that addition of commercial enzyme preparations to poultry feed not only improve the moisture content of droppings, but also improved eggshell quality from wheat and barley based products (Roberts *et al*., 1999). However, this study also found that the addition of enzymes caused some lightening of colour of the eggshell of brown egg layers and a reduction in Haugh Units (Jacobs, *et al*., 2000). These negative effects need to be monitored during the use of these feed enzymes for laying hens (Roberts and Ball, 2004).

Enzyme Phytase is also used in poultry diets to release phytate bound phosphorus in large amount. The supplementation of phytase in diets has been shown to improve eggshell quality, and the effects of phytase supplementation are modified by the levels of calcium and non-phytate phosphorus in diet (Hatten *et al*., 2001; Jamroz *et al*., 2003; Keshavarz, 2003 and Lim *et al*., 2003). Australian diets typically contain up to 10% meat meal so that phosphorus is not limiting. However, recent evidence of synergistic effects of phytase and xylanase in wheat-based broiler diets as reported by Ravindra*n et al*. (1999) warrants consideration of use of phytase in Australian layer diets. Also there is the possibility that less meat meal will be used in poultry diets in the future.

Feed contaminated with mycotoxins has the potential to reduce production and eggshell quality. However, it is likely that these effects are mediated through a reduction in feed intake of the contaminated feed (Suksupath *et al*., 1989). Some hens, as a result of possessing an inherited gene, accumulate significant amounts of trimethylamine in eggs, resulting in an unacceptable fishy odour. This is because of the inability of the hen to oxidize the trimethylamine contained in feed ingredients such as rapeseed meal and fish meal (Pingel and Jeroch, 1997).

2.4.4.4 Stress

There are several types of general stress that can affect eggshell quality. High population densities increase the production of body-checked eggs and are thought to result in contraction of the shell gland while the egg is in the early stages of formation (Reynard and Savory, 1999). Stress can also induce delays in the timing of oviposition when hens retain their eggs and this can result in an increased incidence of white-banded and slab-sided eggs (Reynard and Savory, 1999). The white-banded egg is the one that is retained beyond the normal oviposition time while the slab-sided egg is the one that entered the shell gland while the first egg is still there. The stressors of relocation, or exclusion from nest boxes of birds that normally had access to them, can cause an increase in the incidence of calcium dusted, white-banded, slab-sided and misshapen eggs (Hughes *et al*., 1986; Reynard and Savory, 1999). Even handling of birds which are not used to handling can increase the incidence of cracked eggs (Hughes and Black, 1976). Many of the deleterious effects of general stress on egg quality can be reduced by injection of adrenaline (Hughes *et al.,* 1986; Solomon *et al*., 1987).

2.4.4.5 Heat Stress

High temperatures experienced in most parts of Africa and also other parts of the world can result in the production of smaller eggs and reduced shell quality through a number of physiological processes occurring within the bird (Usayran *et al*., 2001). Heat stress reduces feed intake and limits the availability of blood calcium for eggshell formation. It may also reduce the activity of carbonic anhydrase, an enzyme resulting in the formation of bicarbonate which contributes the carbonate to the eggshell (Balnave *et al*., 1989). Therefore, sodium bicarbonate supplementation during heat stress may improve eggshell quality (Altan *et al*., 2000). Feeding practices during hot weather should focus on ensuring that the birds receive adequate levels of essential nutrients (Daghir, 1995a). Diets need to be formulated to match feed consumption and it should be recognized that birds may tend to eat more during the cooler parts of the day than when the day is hot (Daghir, 1995b).

The form of calcium provided in the diet probably affects the ability of the bird to produce good quality eggshells under hot conditions and it is probable that the provision of half the dietary calcium in a coarse particulate form can improve eggshell quality in heat stressed birds. However, there is no evidence to suggest that increasing the calcium level of the diet has any beneficial effect (Nys, 1995; 1999). It appears that the phosphorus requirement of laying hens increases slightly at hot environmental temperatures (Usayran *et al*., 2001). Other dietary remedies that have been tried to alleviate the negative effects of heat stress include the addition of sodium bicarbonate to the diets and supplementation of dietary electrolytes and addition of aluminosilicates (Balnave and Muheereza, 1997). However, the results of using these additives have been variable (Nys, 1995).

2.4.4.6 Diseases

There are a number of diseases that have been found to affect eggshell quality. Definitely any disease that may affect the health of the bird can also result in defective eggs and eggshell quality. Any pathogenic agent that grows in the tissues of the reproductive tract can cause problems with eggshell formation. Infectious bronchitis has been reported to cause eggshells to be paler in colour and sometimes wrinkled in appearance (Roberts 2004). Egg drop syndrome, as well as causing drops in production may also result in paler colourerd eggshells and other deformities such as soft-shelled eggs or rough shells (Charlton *et al*., 2000). Other diseases that may cause production drops are Newcastle disease, avian influenza, avian encephalomyelitis and Mycoplasma galliseticum (Charlton *et al*., 2000).

2.4.4.7 Production System

The type of production system may influence eggshell quality. However, early problems with cracked eggs can be overcome with the design of furnished cages to include egg saver wires and long nest curtains (Wall and Tauson, 2002). Direct comparisons among the different types of production systems have been made difficult by the shortage of experiments in which all other variables have been maintained constant. Some of the problems with eggshell quality reported from free range systems as reported by Fraser and Bain (1994) may result from inability to ensure a balanced diet for the hens. Some studies found effects of cage density on eggshell quality (Mench *et al.,* 1986) whereas Lee and Moss, (1995) reported no consistent effects.

2.4.4.8 Proprietary Products

Some minerals are necessary in small quantities. These include zinc and manganese which act as cofactors or activators for enzyme that are involved in eggshell formation. The form in which these trace minerals are ingested influences the efficiency with which they can be utilized by the laying hens (Mabe *et al*., 2003). Proprietary products available provide the mineral forms which improve their availability to the birds. Some of these products are EggBooster 49 (Alltech), Iron Egg (All Farm Animal Health Australia) and EggBooster ProPoultry Australia-distributor for Zimpro Animal Nutrition). It would be expected that trace minerals provided in such a form would result in improved eggshell quality. However, it is not always possible to demonstrate improvement as reported by Dale and Strong (1998) and Tangkere *et al*. (2001) so the additional costs of such products require careful consideration in relation to the potential benefit (Roberts, 2004).

2.4.4.9 Bird Strain

As a result of genetic selection, different strains of laying hens vary significantly in eggshell quality, egg size and production (Curtis *et al*., 1985). There are also clear differences between modern commercial birds and traditional breeds of laying fowl (Hockings *et al*., 2003). A number of studies have shown differences in shell strength between brown and white shell colour populations. Taylor and Martin (1928) found the percent shell of brown eggs from Barred Plymouth Rocks to be lower than that of white shelled eggs from White Leghorns. Tyler and Geake (1958) also reported that the white shelled eggs from white Leghorns had thicker shells than the brown shelled eggs from Rhode Island Red breed. Perek and Snapir (1970) reported that the mg per cm shell was greater in White Leghorns than in brown shelled eggs of White Plymouth rock breed. Rodda (1972) also found that a White Leghorn strain had better shell strength than that of a Rhode Island strain. Potts and Washburn (1974) reported that shell strength of commercial white egg strains were in general better than that of brown egg strains. Selection for one characteristic such as production or egg weight can affect other characteristic such as eggshell quality (Poggenpoel *et al.*, 1996).

2.5 Abnormalities in Shell Formation

An eggshell that is smooth is preferred by consumers since rough-shelled eggs fracture more easily and have poor appearance. Eggs with extremely rough, or uneven shells are downgraded. Some eggs have rough pimply appearance. The pimples which are calcium deposits create distortions in the eggshell and it may be hereditary (Jacobs, *et al.,* 2000). Mottled shells are shells with pale translucent spots. Mottling normally develops after the egg has been laid and may be noticeable half an hour after the egg has been laid. This abnormality is also inherited, although a similar effect may be artificially induced (Jacobs, *et al*., 2000).

Another problem with eggshell quality is the incidence of "body checks". Body checks are eggs with shells that have been cracked during shell calcification in the hen and have had a layer of calcium deposited over the cracks before the egg is laid. Body checks which are covered by a thin layer of calcium before being laid are easily detected than those that are covered by a thick layer of calcium before being laid. This abnormality increases when hens are excited more often in the afternoons or early evenings just as the eggshell begins to form in the oviduct. "Body checks" sometimes appear as ridges or bulges on the shell and the more severe the ridges are the ease of detecting the checked area. These shells are usually weaker than the normal shells and are more likely to break in shipment. They also lack consumer appeal (Jacobs, *et al*., 2000).

2.6 Effects of Eggshell Quality on Commercial Egg Production

The per capita egg consumption seem has decreased considerably over the past few years due to the concern over cholesterol and changing eating habits of today's family (Roberts, 2004). This negative effect on consumption adds to the approximate 7% egg loss from the point of lay to the consumer provides an enormous opportunity for dramatic improvement in economic return by improving the shell quality of commercial layers (Washburn, 2008). The eggshell is produced by the shell gland (uterus) of the oviduct, and has an outer coating, the bloom or cuticle. The cuticle seals the pores and helps to reduce moisture loss and also in preventing bacterial penetration of the eggshell (Jacob *et al.,* 2000).

Many factors influence egg breakage which is directly associated with eggshell quality. Although eggshell quality cannot be corrected completely, significant reduction in the number of eggs lost due to poor shell quality can be made (Sabri *et al*., 1999).

The eggshell quality traits of the chicken egg are those characteristics that are measured to determine the quality of the eggshell. The eggshell quality embodies traits such as egg size, egg specific gravity, and shell colour, shell breaking strength, shell deformation, shell weight, percentage shell, shell thickness, and shell ultra structure (Han *et al.,* 1992).

Good shell thickness is an important bioeconomic trait in commercial egg production as it may help to reduce the percentage of cracked eggs. Eggshell quality is associated with hatchability. The quality or structure during the reproductive life of the hen is mostly affected by factors such as the genetic constitution of the bird, diet, climatic conditions, housing and age of the bird (Simons, 1971).

Accurate assessments of eggshell quality may, therefore, allow the producer to vary one or more of these factors that influence eggshell quality in order to improve hatchability (Peebles *et al*., 2000). Eggshell quality has been defined in terms of the ability of an eggshell to resist breakage. The physical measurement of eggshell strength in commercial table eggs can then be used to determine shell quality of hatching eggs.

2.7 Internal Quality of the Egg

The interior of the hen's egg consists of the yolk and albumen. Internal egg quality is measured in several ways (Roberts and Ball, 2004). For many years the most important internal quality traits of the egg have been shown to be albumen height and weight, and yolk index (Johnson, 2000). However according to Jacob *et al.* (2000) the interior quality of the egg is based on air cell size, albumen quality and yolk quality. Kul and Seker (2004) stated that the internal quality traits of the egg are as follows; the albumen weight, albumen height, albumen ratio, Haugh unit, yolk diameter, yolk height, yolk weight, yolk index and yolk ratio. However, the most important internal quality traits are the yolk index and the Haugh unit since they are the best indicators of egg quality (Isikwenu *et al*., 1999), and the higher the yolk index and the Haugh unit the more desirable the egg quality (Ayorinde, 1987).

2.7.1 Albumen Quality

Albumen quality is a measurable trait and it is a function of the height of the inner thick albumen, the Haugh unit is the outcome of this measurement, or more properly the albumen height alone (Cetin *et al.*, 2002). The albumen has a major influence on the overall interior egg quality. Thinning of the albumen is a sign of albumen loss and this can be seen clearly when a stale egg is broken on a smooth flat surface, the yolk is flattened and often displaced to one side. However, a fresh egg when carefully broken out the round yolk stays in a central position surrounded by thick albumen (Jacob *et al*., 2000).

2.7.1.1 Effects of Some Environmental Factors and Genetic Differences on Albumen Quality

Albumen quality is influenced by genetic factors and environmental factors such as temperature, humidity, presence of carbon dioxide, pH and storage time (Fayeye, *et al*., 2008); others include nutrition and the hen's age (Roberts *and* Ball, 2004).

2.7.1.1.1 Temperature and humidity

Albumen quality is not only an important indicator of egg freshness but also important for the egg breaking industry because albumen and yolk have different functions (Koelkebeck, 1999). Storage time and temperature appear to be the most crucial factors affecting albumen quality or Haugh unit (HU). The Haugh unit as described by Haugh (1937) is calculated from the height of the inner thick albumen. Visual appearance of the albumen has also been used extensively to describe egg quality (Hunton, 1987). Excess loss of water from the egg through evaporation at a rate that is influenced by the temperature and relative humidity during the long-term storage conditions has generally been reported to be detrimental to table and hatching egg quality (Walsh *et al*; Scott *et al*., 2000).

2.7.1.1.2 Storage time, pH and the presence of carbon dioxide

It has been reported by some researchers that there is a decline in hatchability after seven (7) days of storage (Mayes and Takeballi, 1984). pH is an important environmental factor used in describing the changes in albumen quality over time during storage, although its measurement is time consuming. Albumen pH increases with the loss of carbon dioxide from the egg. An increase in pH and dry matter has been reported to extend the storage time from two (2) to thirty (30) days. There is also a decrease in viscosity and changes in taste and flavour in ageing eggs (Scoltyseek, 1981).

2.7.1.1.3 Age of bird

Age of the hen is another factor which could possibly influence albumen quality especially that of freshly laid eggs. Initial albumen quality rapidly decreases with advancing flock age. However forced moulting is beneficial in restoring albumen quality in aged hens. Elibol *et al.* (2002) have reported that as the age of the bird increases the albumen height decreases even as the egg weight and the total amount of albumen increase.

2.7.1.1.4 Nutrition of the Bird

Although number of nutritional factors have been reported to affect albumen quality within the limits of acceptable commercial practice, albumen quality is largely unaffected by nutrition (Williams, 1992). The albumen quality might be related to the protein source consumed by the laying hen. Egg albumen is about 12% protein of which the main ones are ovalbumin (54%), ovotranferrin (13%), ovomucoid (11%), alpha and beta ovomucin (1.5 – 3.0%) and lysozyme (3.5%) (Johnson, 2000). All except lysozyme are glycoproteins. There are many minor proteins in albumen but few of them have been identified (Robinson, 1987; Li-Chan and Nakai, 1989).

Another possible factor influencing albumen quality could be dietary electrolyte balance. Unlike most other animals producing a product, like meat, milk or fetus where a constant uniform supply of nutrients is required throughout the day, the hen first lays down approximately six grams of protein in an egg in four to five hours and then approximately the same amount of calcium carbonate (shell) during the next eighteen to twenty hours. Therefore the possibility of dietary electrolyte balance influencing acid-base balance in the body must be considered.

2.7.1.1.5 Genetic Difference of Bird

A research was carried out to investigate whether the marked individual bird variation noted for runny albumen could be explained by genetic make up of hens. It suggested that there is a genetic influence on albumen quality as pullets from mothers with good or compact albumen characteristics produced eggs with spreading albumen characteristics (Islam *et al* 2001).

2.7.2 Yolk Quality

There are two component to yolk quality; the colour of the yolk and the strength of the perivitelline membrane which surrounds the yolk (Kirunda and Mckee, 2000) . Yolk colour varies considerably depending on the parts of the world and pigments found included in the diet of the hen and it could be of natural or synthetic origin. If the hen gets plenty of yellow or orange plant then the colour of the yolk becomes yellowish or dark yellow. If the perivitelline membrane is weak the yolk may break easily (Kirunda and McKee, 2000). The yolk of freshly laid egg is round and firm.

As the yolk ages it absorbs water from the albumen and increases in size. This weakens the perivitelline membrane and gives the yolk a flattened shape and occasionally a more or less fractured yolk. It is essential that the perivitelline membrane remains intact and strong in order to prevent the contents of the albumen and yolk from mixing. If this occurs, the quality of the egg and consumer acceptance of these eggs decline due to mottling. The degree of yolk mottling is related to the amount of degeneration of the perivitelline membrane (Li-Chan and Nakai, 1989).

2.8 Effect of Hen Weight on Some Egg Quality Trait

One of the main factors influencing egg size is body size (Robinson and Sheridan, 1982; Summer and Leeson, 1983). According to Philip (1970) body weight is regarded as a function of framework or size of the animal and its condition. Variation in body weight within a flock can be attributed to genetic variation and environmental factors imposed on individual birds (Ayorinde and Oke, 1995). Body weight in poultry is known to be moderately to highly heritable therefore selection of heavier individuals in the population should result in genetic improvement in the trait. It has been reported by Du Plessis and Erasmus (1972) that larger hens within strains lay larger eggs than those with smaller body weight. This was supported by Ricklefs (1983) that larger body size resulted in large egg length, width and mass, and all factors affecting egg weight. Although, egg numbers have been shown to decrease with increasing body weight, the weight of the egg increases as the body weight increases (Oluyemi and Roberts, 1979).

2.9 Effects of Genetics and Breeding on Egg Quality Traits

Heritabilities for egg quality traits are moderate to high and there are strong genetic correlations between egg weight and its component parts, that is, the weights of the shell, albumen and yolk. Egg quality is affected by selection on body weight, even though this effect may differ between experiments. The differences may originate from the breeding lines. Although selection on egg production could increase yolk content, selection work on egg quality traits has shown genetic variation for yolk related characters (Minvielle and Oguz, 2002). The yolk index and haugh unit in Fulani-ecotype chickens were reported to be higher than those obtained from Yaffa and Isa Brown layers (Oguike and Onyekweodiri, 1999; Fayeye *et al.*, 2008). The mean shell weight was also higher in the former than the latter (Ayorinde, 1987).

2.10 Types of Correlation and Estimation

Correlation is the extent to which an improvement in one trait will cause a simultaneous change in other traits. Correlations in traits are of interest for three important reasons.

1. As a result of its genetic causes through the pleiotropic action of genes. Pleiotropy is simply the property of a gene whereby it affects two or more characters or traits and the

degree of correlation due to pleiotropy expresses the extent to which two traits are influenced by the same genes. Some genes may increase both characters or traits and that is positive correlation, while others increase one and reduce the other and that is a negative correlation. When two traits are independent then their correlation is zero.

2. In connection with changes brought about by selection.

3. As a result of natural selection.

Association between two characters that can be directly observed is the correlation between values of two traits on the same animal, or the phenotypic correlation. It is determined from measurement of the two characters in a number of individuals in a population (Falconer and Mackay, 1996). However there are two main components of phenotypic correlation between characters, genetic correlation and environmental deviation. These two assess independently the genetic and environmental causes of correlation. Genetic cause of correlation is mainly as described in 1 above and the environmental cause of correlation is where two or more characters are influenced by the same differences of environmental conditions together with the non-additive deviations (Falconer and Mackay, 1996).

Genetic correlation is the proportion of variance between two traits that is due to genetic causes. Outside the theoretical boundary case of traits with zero heritability, the genetic correlation of traits is independent of their heritability (Falconer and Mackay,1996). That is, two traits can have very high genetic correlation even when the heritability of each is low and vice versa. The genetic correlation then, tells us how much of genetic influence on two traits is to both. Therefore the genetic correlation is the correlation between the animal's breeding value for one trait and the same animal's breeding value for another trait (Neale and Maes, 1996). If genetic correlation is positive it suggests that the two traits are influence by common genes. This means that genetics contributes significantly to these two trait (Neale and Maes, 1996).

In many cases the estimate of phenotypic correlation is reported smaller in magnitude than that of the corresponding genetic correlation (Falconer and Mackay, 1996). Such results may seem a little unexpected at first sight, since the phenotypic correlation includes the genetic correlation and environmental correlation one might expect the phenotypic correlation to be greater than the genetic correlation. The explanation in most cases is as a result of negative environmental correlation between the two traits (Falconer and Mackay, 1996).

Phenotypic values of different traits in the same environment are often correlated. Environmental factors and genetic factors are reasons for correlation. Similar to partitioning phenotypic variance, phenotypic correlation can be decomposed into genetic and environmental components (see equation 1).

$$\mathrm{r_p} = \mathrm{r_A} + \mathrm{r_E} \qquad (1)$$

$\mathrm{r_p}$ is the phenotypic correlation which is a function of genetic correlation ($\mathrm{r_A}$) and the environmental deviation ($\mathrm{r_E}$) between traits x and y.

$$r_p = \frac{cov_{Pxy}}{[\sigma^2{}_{Px}\sigma^2{}_{Py}]^{1/2}} = \frac{cov_{Axy}}{[\sigma^2{}_{Ax}\sigma^2{}_{Ay}]^{1/2}} + \frac{cov_{Exy}}{[\sigma^2{}_{Ex}\sigma^2{}_{Ey}]^{1/2}} \quad (2)$$

Where COV_{Axy} is the genetic covariance, COV_{Exy} is the environmental covariance; σ^2 is the variance and subscripts are additive genetic (A) or environmental (E) variance for traits x and y.

$$r_p = \frac{cov_P}{[\sigma^2{}_{Px}\sigma^2{}_{Py}]^{1/2}} \quad (3)$$

$$cov_P = r_p\sigma_{Px}\sigma_{Py} \quad (4)$$

$$r_A = \frac{cov_A}{[\sigma^2{}_{Ax}\sigma^2{}_{Ay}]^{1/2}} \quad (5)$$

$$cov_A = r_A\sigma_{Ax}\sigma_{Ay} \quad 6$$

$$r_E = \frac{cov_E}{[\sigma^2{}_{Ex}\sigma^2{}_{Ey}]^{1/2}} \quad (7)$$

$$cov_E = r_E\sigma_{Ex}\sigma_{Ey} \quad (8)$$

$$cov_p = cov_A + cov_E \quad (9)$$

$$r_P\sigma_{Px}\sigma_{Px} = r_A\sigma_{Ax}\sigma_{Ay} + r_E\sigma_{Ex}\sigma_{Ey} \quad (10)$$

The phenotypic correlation can be simplified by substituting the square root of variance (see equations 11-13).

$$h^2 = \frac{\sigma_A^2}{\sigma_P^2} \quad (11)$$

$$\sigma_A^2 = h^2\sigma_P^2 \quad (12)$$

$$\sigma_A = h\sigma_P \quad (13)$$

The square root of additive genetic variance (σ_A) is the product of square root of heritability (h) and square root of the phenotypic variance (σ_P) (see equation 13).

$$\sigma_e^2 = 1 - h^2 \quad (14)$$

$$\sigma_e = [1 - h^2]^{1/2} \quad (15)$$

$$\sigma_e^2 = \frac{\sigma_E^2}{\sigma_p^2} \quad (16)$$

$$\sigma_E^2 = \sigma_e^2 \sigma_p^2 \quad (17)$$

$$\sigma_E = \sigma_e \sigma_p \quad (18)$$

The σ_e^2 is the remaining ratio of the total phenotypic variance after subtracting the heredity. In other words, σ_e^2 is the ratio of environmental variance and phenotypic variance. Phenotypic variance can be formulated as the product of σ_e and σ_p.

Phenotypic correlation can be written as the function of heritability, genetic and environmental correlations (see equation 19).

$$r_P = r_A h_x h_y + r_E \left[(1 - h_x^2)(1 - h_y^2) \right]^{1/2} \quad (19)$$

This is how phenotypic correlation changes as heritability increases or decreases.

2.11 Phenotypic Correlation Within and Between Internal and External Quality Traits

2.11.1 Phenotypic Correlation between the External Quality Traits

The weight of the egg is the most important external quality trait of the egg influencing the weight of newly hatched chicks and hatching performance (Farooq *et al*., 2001). The existence of a significant positive correlation between egg weight, shell weight and shell thickness has been reported by Farooq *et al*. (2001). This provides an indication for better prediction of eggshell weight and thickness from other quality traits (Khurshid *et al*., 2003).

There was also a significant and positive correlation (Farooq *et al*., 2001b) between egg weight, egg length and egg width in their experiment with Fayomi eggs. Shell weight and thickness which are known to affect hatchability of eggs cannot be determined unless the egg are broken (Murad *et al*., 2001). However, Khurshid *et al*. (2003) found significantly positive correlation between eggshell weight with egg length and width. They were also able to predict with accuracy shell thickness from egg weight, length and width as a result of a significant association of eggshell thickness with egg width (Farooq et al., 2001a; Gulnawaz, 2002). Kul and Seker (2004) found a negative correlation between egg weight and shape index which is consistent with the findings Altan et al. (1995) and Ozcelik (2002) in hen's egg and quail's egg respectively.

In Table 1 phenotypic correlation between external quality traits of egg quality from five breeds of chicken is presented (Islam and Dutta, 2010). It is observed that there exist significant ($p<0.001$) and positive correlation between shell weight and shell ratio for all breeds. They also found a significant ($p<0.01$) and positive phenotypic correlation between egg weight egg volume(egg length and egg width) for the Sonali breed.

Table 1 Phenotypic correlation between external quality traits of egg quality from five breeds of chicken

1BREED	Egg Weight vrs Egg Volume	EggWeight vrs Shell Weight	Egg Weight vrs Egg Shape Index	Shell Weight vr Shell Ratio
IND	0.48	-0.10	-0.17	0.97***
BRO	0.26	0.37	-0.21	0.90***
FAY	0.43	-0.20	-0.21	0.97***
RIR	0.62	0.47	-0.49	0.85**
SON	0.93***	0.24	0.05	0.82**

Source: Islam and Dutta (2010)

*= P<0.05; ** = P<0.01; *** = P<0.001

2.11.2 Phenotypic Correlations between Internal Quality Traits

Kul and Seker (2004) reported a statistically significant negative correlation between the albumen height and the yolk ratio. They found statistically significant positive correlations between the albumen index and albumen height, albumen weight, haugh unit and yolk height. These indicate that an improvement of the albumen index will result in an improvement in albumen weight and the albumen ratio (Ozcelik, 2002). This can be used for the estimation of the haugh unit, an important criterion for determining internal quality of the egg. Akbas *et al.* (1996) found a statistically significant phenotypic correlation between yolk height and albumen height and haugh unit and between albumen height and haugh unit. Ozcelik (2002) found statistically significant correlations between albumen height and the haugh unit; the yolk ratio and yolk height; albumen ratio and the haugh unit; and between haugh unit and yolk height. These findings agree with The findings of Olawumi and Ogunlade, 2008 as shown in table 2.

Table 2 The phenotypic correlation between internal egg quality traits

Internal egg quality traits	Yolk weight	Yolk width	Yolk height	Yolk ratio	Albumen weight	Albumen length	Albumen width	Albumen ratio	Haugh unit
Yolk weight	1.00	0.62***	0.44***	0.64***	0.18	0.03	0.22*	-0.62***	-0.04
Yolk width	-	1.00	0.17	0.31***	0.21*	0.001	0.05	-0.29**	-0.07
Yolk height	-	-	1.00	0.08	0.34***	0.36**	-0.03	-0.04	0.34***
Yolk ratio	-	-	-	1.00	-0.63***	-0.10	-0.03	0.90***	-0.05
Albumen weight	-	-	-	-	1.00	0.19*	0.18*	0.60***	0.06
Albumen height	-	-	-	-	-	1.00	-0.35***	0.15	0.97***
Albumen width	-	-	-	-	-	-	1.00	-0.12	-0.41***
Albumen ratio	-	-	-	-	-	-	-	1.00	0.11
Haugh unit	-	-	-	-	-	-	-	-	1.00

: p<0.05; **: p<0.01; ***: p<0.001

Source: Olawumi and Ogunlade (2008)

2.11.3 Phenotypic Correlation between External and Internal Quality Traits

In reproductive flock of poultry it is very important to obtain a large number of egg with normal structure, normal morphological composition and interior quality. These elements have very significant influence on biological value of the egg which determines normal development of the embryo. Weight of the egg albumen was predicted with accuracy from the egg weight, egg width and length due to a significant correlation between them (Khurshid et al., 2003). They were also able to predict with accuracy the weight of the yolk from the egg weight, length and width due to a significant positive correlation between them.

However, a negative correlation value was obtained for shell weight and albumen ratio. There were no significant correlations between the shape index and internal quality traits with the exception of the albumen weight and yolk weight (Olawumi and Ogunlade, 2008).

These findings were supported by Ozcelik (2002) and Kul and Seker (2004). Oluwami and Ogunlade (2008) (see Table 3) also found that there was a negative but non - significant correlation between shell thickness and almost all the internal quality trait of the egg. He also found that almost all the internal quality traits of the egg such as albumen height, albumen weight, yolk diameter, yolk height and yolk weight changed at significant levels depending on the change which occurred in the egg weight.

Table 3 External and internal quality traits

Internal egg quality trait	Egg weight	Egg length	Egg width	Shell weight	Shell thickness	Shell ratio	Shape index
Yolk weight	0.55***	0.34***	0.48***	0.47***	-0.09	-0.18*	-0.03
Yolk height	0.45***	0.31***	0.36***	0.19*	-0.13	-0.09	-0.07
Yolk width	0.42***	0.28**	0.42***	0.26**	0.03	0.02	-0.02
Yolk ratio	-0.29**	-0.22*	-0.26**	-0.03	-0.14	0.16	0.05
Albumen weight	0.91***	0.64***	0.77***	0.35***	-0.03	-0.21*	-0.13
Albumen height	0.15	0.17	0.04	-0.06	-0.23*	-0.17	-0.14
Albumen width	0.29***	0.11	0.27**	0.42***	0.12	0.31***	0.08
Albumen ratio	0.21*	0.24*	0.14	-0.33***	-0.17	-0.56**	-0.14
Haugh unit	0.004	0.07	-0.10	-0.15	-0.23*	-0.18	0.13

*: p<0.05; **: p<0.0; ***: p<0.001
Source: Olawumi and Ogunlade (2008)

The findings of Islam and Dutta, 2010 as shown in **Table 4** indicate significant and positive phenotypic correlations between egg weight and yolk and between egg weight and albumen weight. They reported a negative but insignificant phenotypic correlation between egg weight and both albumen ratio and yolk ratio. Both yolk weight and albumen weight correlated negatively but insignificant with the egg weight.

Table 4 Phenotypic correlation between external and internal quality traits of egg quality from five breeds of chicken

1BREED Table	EW vrs YW	EW vrs AW	EW vrs YR	EW vrs AR	ESI vrs YW	ESI vrs AW
IND	0.59	0.45	0.37	-0.25	-0.21	0.27
BRO	0.28	0.82**	-0.19	0.19	-0.38	0.10
FAY	0.66*	0.13	0.49	-0.55	0.001	-0.15
RIR	0.72*	0.96***	0.12	-0.17	-0.46	-0.44
SON	0.12	0.70	-0.42	0.52	-0.006	-0.13

Source: Islam and Dutta (2010)

Broiler (Cobb 500); FAY = Fayoumi; RIR = Rhode Island Red; SON =Sonali; EW= Egg weight; AW = Albumen weight; YR =Yolk ratio; AR = Albumen ratio; ESI =Egg shape index; vrs = versus; ns = non significant; *= P<0.05; ** = P<0.01; *** = P<0.001

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

One thousand five hundred broiler parents were housed in deep litter pens in a ratio of one male to ten females at the Breeding Farm of Darko Farms and Company Limited, a private owned poultry farm, situated at Atwima Manhyia, a suburb of Kumasi.

Table 5 shows the energy content and percentage protein of the various diets given from day –old to the laying period;

Table 5. Energy levels and crude protein content of the various diets fed the broiler parents

DIET	AGE (WEEKS)	ENERGY CONTENT(Kcal/Kg)	CRUDE PROTEIN CONTTENT (%)
Chick mash	0-7	2930	21.0 CP
Grower mash	8-17	2800	16.0 CP
Pre-breeder	18-24	2820	18.0 CP
Breeder mash I	25-45	2820	17.0 CP
Breeder II	>45	2810	16.5 CP

3.2 Vaccination

Table 2 shows the various vaccinations given to the birds during the rearing period. These vaccinations started on the seventh day of the first week after glucose had been given on the first and brooding needs had been taken care of. On the second day an antibiotic, Fernosvi, was administered for four days and repeated in the third week.

Table 6. Vaccinations given during the rearing period

Age (week)	Vaccinations
1	HB1+ H120
2	Gumboro (288E)
4	Lasota + H120
6	1st fowl pox
8	Lasota
10	1st Coryza
12	AE
14	Lasota
15	2nd Coryza
17	2nd fowl pox
19	New Cavac + 1B
21	Gumboro (inactive)

Although the birds started laying at the age of twenty four weeks the eggs used for the experiments were eggs collected between the ages thirty two and forty six weeks. This was because egg production reached its peak at thirty two weeks which ensured that that eggs collected over the eleven week period were quite uniform in size.

3.3 Measuring Instruments

1. 0.001g sensitive electronic scale (model: CS 5000, OHAUS, Ohaus cooperation USA) was used for weighing the egg.
2. A pair of vernier calipers sensitive to 0.1mm was used for measuring the egg length, width and yolk diameter.

3. Two flat stainless steel metal pans each weighing 42.8g and of 8cm in diameter were used in receiving the content of the broken eggs. One pan for holding the yolk and the other the albumen after a careful separation of the two.
4. A tripod micrometer sensitive to 0.01mm was used for measuring the height of yolk and albumen.
5. A micrometer screw gauge sensitive to 0.01mm was used for measuring the shell thickness.

3.4 Sampling method

The number of eggs collected each week ranged from nine thousand (9,000) to eleven thousand (11,000), and were used for the research for a period of four months. Out of these a sample of thirty (30) eggs were randomly selected from each week's egg collection and assessed individually for the evaluation of the egg quality traits. However, soft, cracked and very small eggs were not used in the experiment. The measurement of the external and internal quality traits of the eggs were carried out at the Department of Physics' laboratory at the Kwame Nkrumah University of Science and Technology where the various instrument listed above were available.

3.5 Measurement of traits

3.5.1 Egg weight

All the thirty eggs collected each week were weighed one at a time by placing them on an electronic scale to determine their weights. Each week's egg weight was the average or the mean of all the thirty eggs.

3.5.2 Egg length and egg width

The width represent the narrow circumference where as the length represents the broader circumference of the egg. The values were then used to determine the egg shape index.

3.5.3 Eggshell weight

After an egg had been cracked open the eggshell was isolated after emptying its contents by washing it under slowly flowing water to ensure that all the remains of albumen were completely removed but making sure to retain any shell fragments or pieces. The external cuticle and internal shell membranes were also retained. The washed shells were then labeled and left to dry in the open air for twenty four hours after which they were weighed.

3.5.4 Shell thickness

Samples of shell taken from the narrow end, broad end and equator were measured to determine of shell thickness. The average shell thickness was obtained and recorded in mm from the values of these three parts.

3.5.5 Yolk height, albumen height and yolk diameter

Each egg was carefully broken into a flat stainless steel pan and the yolk height and albumen height were measured. The height of the albumen was taken in the thick albumen surrounding the yolk. This was done by choosing one flat portion of the albumen to measure the height of the albumen. In fresh eggs the albumen may not have a flat portion in which case the height of the albumen was measured half way between the yolk and the edge of the albumen. The yolk diameter was also determined.

3.5.6 Yolk weight and albumen weight

The yolk was weighed after breaking the egg on a flat pan and gently separating the yolk from the albumen. The albumen weight was taken by subtracting the weight of the yolk and the shell weight put together from the weight of the whole egg, since it was very difficult to extract all the albumen from the shell.

3.5.7 Estimation of some internal and external quality traits of egg

Some internal and external quality traits of the eggs were estimated using the following reported methods on the basis of the aforementioned measurement: (Marks and Kiney, 1964; Nesheim *et al.*, 1979; Csuka and Ladec, 1981; Stadelman, 1986; Yannakopoulos and Tserveni-Gousi, 1986; Yacin *et al.*, 1990; Altan *et al.*, 1995).

$S = 3.9782W^{0.75056}$

S = Egg surface area (cm^2) Altan *et al.*, 1995.

W = Egg weight (mg)

And 3.9782 is a constant (Marks and Kiney, 1964);

Unit surface shell weight (mg/cm^2) =Eggshell weight (mg)/Egg surface area (cm^2) (Stadelman, 1986);

Shape index (%) = [Width (cm) / Height (cm)] * 100

Shell ratio (%) = (Shell weight / Egg weight) * 100

Albumen ratio (%) = (Albumen weight / Egg weight) * 100

Yolk index (%) = (Yolk height / Yolk diameter) * 100

Yolk ratio (%) = (Yolk weight / Egg weight)* 100 (Csuka and Ladec, 1981)

Albumen weight (g) = Egg weight – (Yolk weight + Shell weight)

Haugh unit (Hu) = 100 log ($H + 7.57 – 1.7W^{0.37}$)

H = Albumen height (mm),

W = Egg weight (g) (Haugh, 1937)

3.6 Statistical Analysis

Data collected were analyzed using Microsoft spread sheets and Statistical Package for Social Scientists (SPSS). The descriptive statistical analyses were presented mostly as their measures of central tendency and their measures of dispersion. Spearman's coefficient of correlation and hypothesis testing were the inferential statistical method used to establish the extent to which the phenotypic correlation between the internal and external quality traits of the eggs. The significance of the associated correlation values were tested using the p-value approach of significance testing (Snedecor and Cochran, 1980).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Internal and External Quality Traits of Eggs

Table 10. Descriptive Statistics of internal and external egg quality characteristics

Traits (n=330)	Mean	Minimum	Maximum	Variance	Std. Dev.
External egg quality traits					
Egg weight (g)	59.37	48.34	76.50	23.15	4.81
Egg width (cm)	4.35	3.81	5.78	0.05	0.22
Egg length (cm)	5.64	4.04	9.15	0.26	0.51
Shape index (%)	77.59	53.84	98.44	39.31	6.27
Shell thickness (mm)	0.54	0.30	1.14	0.01	0.12
Unit surface shell weight (mg/cm^2)	3.90	3.70	4.15	0.01	0.08
Shell weight (g)	7.35	3.09	21.35	9.47	3.08
Shell ratio (%)	12.40	5.73	32.83	26.87	5.18
Internal egg quality traits					
Albumin height (mm)	5.94	3.07	13.34	1.58	2.51
Albumin weight (g)	32.63	19.29	46.72	5.35	28.58
Albumin ratio (%)	54.80	34.24	65.83	6.69	44.58
Haugh unit (HU)	75.10	48.46	110.98	10.76	115.84
Yolk diameter (mm)	42.11	35.00	50.00	1.94	3.75
Yolk height (mm)	16.35	11.12	23.04	1.71	2.91
Yolk weight (g)	19.43	11.59	29.72	2.43	5.92
Yolk index (%)	38.81	10.55	52.98	4.50	20.28
Yolk ratio (%)	32.84	20.77	46.55	4.17	17.40

The descriptive statistics of the quality traits examined in this research are shown in **Table 7**. The overall mean values obtained for the external quality traits such as; egg weight, egg width, egg length, shell thickness, shell weight, shell ratio, egg shape index, and unit surface shell weight respectively were as shown in **Table 7** above.

The mean values obtained for internal quality traits were yolk weight, yolk diameter, yolk height, albumen weight, albumen height, Haugh unit, yolk index, yolk ratio, and albumen ratio respectively as shown in table 7 above.

4.1.1 The mean egg weight

The overall mean egg weight obtained in this research was 59.37g with a standard deviation of 4.81g and this describes how varied the egg weights are about the overall mean. This variation is accounted for by the weekly interval between which eggs were collected and sent to the laboratory for evaluation and eggs collected each week might have come from different pens.

The overall mean egg weight differed slightly from those recorded by other researchers such as Wolanski *et al*. (2007), who reported values ranging between 63.4 to 66.0g when they determined relationships among egg characteristic and early growth in ten broiler breeder strains at ages between 46 weeks and 57 weeks. It is obvious that the difference could be due to strain effects or age difference between breeder flocks.

It also differs from the values obtained by Romero *et al.* (2009) with Ross 708 broiler breeders which produced egg weights between 60.0g and 62.3g. The mean egg weight recorded in the present study was much higher than the 46g reported by Islam and Dutta (2010) in Cobb500 broiler breeder eggs at the Department of Zoology University of Rajshahi, Bangladesh.

According to Islam and Dutta, (2010) the average weight of the eggs gives an idea of the quality of hatchlings which will be obtained from these eggs. This is because chick weight as a ratio of egg weight for broilers is between 69% and 72% (Islam and Dutta, 2010). Wolanski *et al*. (2006) compared broiler hatching eggs from commercial lines and pure lines. The eggs from the commercial lines weighed 64.4g and those from the pure lines weighed 65.7g resulting in chicks weighing 2.5g higher, on average, in pure lines compared with commercial lines.

The relationship between egg weight and hatchling weight (Saatci *et al*., 2005) was also clarified by Altan *et al.* (1995*)* who reported that egg weight is positively related to changes in hatchling weight. The positive correlation between egg weight and chick weight was also reported by Skewes *et al.* (1988),), Raju *et al.* (1997) and Shanawany (1987). According to Leeson and Summers (2000) increase in egg weight beyond 70g may tend to reduce hatchability because they produce more heat during incubation which eventually leads to increased embryonic mortality.

4.1.2 Eggshell quality

The values relating to external quality traits obtained in this study are similar to those obtained by Olawumi and Ogunlade (2008) in ISA brown eggs except the shell thickness, shell ratio and the shell weight which were two units each lower than those obtained in the present research. The mean shell weight obtained in this study was higher than what was recorded by Fayeye *et al.* (2008) for Fulani - ecotype chickens but the shells were thicker in Fulani – ecotype chickens.

This means that eggshell quality of Cobb 500 broiler hatching eggs used in this research was inferior to those of the Fulani- ecotype chicken. Apart from egg weight, shell thickness and shell weight, shape index is also an important external quality trait of the egg from the .point of mechanical handling of eggs in commercial egg production. Shell thickness is an important bioeconomic trait in commercial egg production as it helps to reduce the percentage of cracked eggs. It is also important in hatching eggs due to the role the intact shell plays as a chamber for the embryo and as a medium for the exchange of gases during embryo development. Hence, deficiencies in external quality traits of the incubated eggs have deleterious effect on hatching performance and future development of the hatchlings (Shanaway, 1987). Shell weight values lower than that recorded in the present study was recorded by Oguike and Onykweodiri (1999) for Yaffa and ISA Brown layers and that recorded by Joseph and Oduntan (1999) for eggs of unclassified Nigerian local chicken. The mean shell weight value was slightly higher than those obtained by Ogunlade and Olawumi (2008).

4.1.3 Internal egg quality traits

Among the internal egg quality parameters, yolk weight, albumen weight and their ratios respectively are very important from their nutritional and cholesterol content viewpoints (Olawumi and Ogunlade, 2008). The results indicated a greater proportion of albumen (54.80%) compared to yolk (32.84%) and shell (12.40%) of the total egg. This is similar to the findings of Sezer (2007) who recorded an albumen ratio and yolk ratio of 60.83% and 30.49% and their total constituted over 90% of the total egg weight. However the findings of this research were contrary to those of Islam and Dutta (2010) who obtained 64% and 20% for albumen ratio and yolk ratio respectively for Cobb500 eggs.

The yolk height (16.35mm) was greater than the albumen height (5.94mm). The Haugh unit and yolk index recorded in this research differ slightly from the findings of Sezer (2008) who recorded Haugh unit and yolk index of 89.98 and 46.47% respectively. The composition of the egg with regards to percentages of yolk weight, albumen weight and shell weight respectively, varies as a result of differences in the genetic makeup of the birds and their management or even the age of the hen. It is reported that changes in interior egg quality traits could be expected during egg production period (Narushin and Romanov, 2002).

According to Ihekoronye and Ngoddy (1985) high quality eggs generally have haugh unit of 70 and above. Therefore the Haugh unit and the yolk index in the present study suggest that the birds from which the eggs were obtained are desirable because the two indices are the best indicators of internal egg quality (Isikwenu *et al.*, 1999)

4.2 Correlation Analysis

4.2.1 Phenotypic correlation between external quality traits

The phenotypic correlation of the external quality traits are as shown in **Table 8**. The results obtained in this research indicate a statistically significant ($p<0.01$) and positive phenotypic correlation between the egg weight and egg width, and egg weight and egg length.

Table 8. The phenotypic correlations between external egg quality traits

External egg quality traits	Egg Weight	Egg Width	Egg Length	Shape index	Shell Thickness	Unit surface shell weight	Shell Weight	Shell ratio
Egg weight	1.00	0.469**	0.468**	-0.184**	0.006	0.999**	0.048	-0.129*
Egg width		1.00	0.407**	0.218**	- 0.008	0.467**	- 0.135*	-0.211**
Egg length			1.00	-0.788**	0.028	0.463**	-0.185**	-0.267**
Shape index				1.00	0.040	-0.181**	0.132*	0.169**
Shell thickness					1.00	-0.005	0.038	0.040
Unit surface shell weight						1.00	0.051	-0.127*
Shell weight							1.00	0.977**
Shell ratio								1.00

*:p<0.05, **: p<0.01

This according to Pandey *et al*. (1986) is because both factors determine the volume and holding capacity of the egg and consequently the weight of the egg. However, there was a statistically significant but negative phenotypic correlation value of -0.184 obtained between egg weight and shape index, and this agrees with the findings of Olawumi and Ogunlade (2008) for ISA Brown Layer Breeders and Zhang *et al*. (2005) for Brown -Egg Dwarf Layers. The value obtained in both researches was -0.09

The negative phenotypic correlation value between egg weight and shape index obtained in this study was similar to that reported by Choprakarn *et al.* (1998) on chickens. This implies that the increase in egg width as a result of increase in the weight the egg weight is more than the increase in egg length association with increase in egg weight. Thus as the weight of the egg increases the shape index which is the ratio of egg width to egg length decreases so that the heavier the egg the more rounded it becomes (Pandey *et al*., 1986). This could eventually create handling and transportation problems since the shape of the egg is a result of function and matter of natural convenience rather than aesthetic perfection.

There was a statistically significant positive phenotypic correlation ($p<0.01$) between egg weight and the unit surface shell weight (0.999). This may be due to the fact that the egg weight according to Stadelman (1986) is directly proportional to the unit surface shell weight. Although the egg weight correlates positively with shell weight the correlation was not significant (0.048) in this study. This agrees with the findings of Islam and Dutta (2010) who also found a positive but not significant phenotypic correlation value between egg weight and shell weight of Cobb500 broiler eggs. Wolanski *et al.* (2006) reported a strong positive correlation value of 0.78 between shell weight and shell thickness in broiler breeder eggs. However in this research, the correlation between shell weight and shell thickness was positive but not significant. In one other study conducted by Olawumi and Ogunlade reported 2008 there were statistically significant high positive phenotypic correlations between egg weight and egg length (0.66), egg width (0.88) and shell weight (0.61) as reported by Olawumi and Ogunlade (2008).

The insignificant positive correlation between the egg weight and shell weight observed in this research was because, as egg weight increases the shell weight also increases but not as much as the increase that occurred in other components of the egg (Keshavarz, 2003). This explains the negative phenotypic correlation that exists between egg weight and shell ratio in this study.

The positive phenotypic correlation value of 0.006 obtained between the egg weight and the shell thickness was insignificant ($p>0.05$) compared to 0.32 reported by Zhang *et al*. (2005), 0.26 by Standelman (1986); 0.05 by Olawumi and Ogunlade (2008) and 0.21 by Kul and Seker (2004). Heavier eggs are expected to have higher shell weight than lighter eggs. This assertion was revealed in this study by positive phenotypic correlation between egg weight and shell weight though not significant. The relationships between the egg weight and the shell weight, and that between egg weight and shell thickness observed in this research are not strong, thus the weight of the eggs used in this study cannot be used to determine these traits (shell thickness and shell weight).

Shell weight to total egg weight (shell ratio) is a much more reflective value of shell quality than absolute shell weight (Tyler, 1967; Abdallah *et al*., 1993). Shell ratio in this research was found to have a statistically significant ($p<0.05$) but negative phenotypic correlation of -0.129 with egg weight. There was also a statistically significant negative phenotypic correlation between shell ratio and egg length (-0.267) and between shell ratio and egg width indicating that larger eggs had proportionately less shell weight. In other word as the weight of the egg increases the shell weight increases marginally resulting in a reduced proportion of the shell though some other components of the egg increased. Kul and Seker (2004) reported a statistically significant negative phenotypic correlation value of -0.22 between egg weight and the shell ratio. Hence, it can be speculated that selection for increased egg weight will result in decreased shell quality though it requires genetic correlation to make a factual conclusion.

The results of this work do not agree with the findings of Olawumi and Ogunlade (2008) who reported an insignificant but positive phenotypic correlation value of 0.04 between the egg weight and the shell ratio.

In this research the egg weight had a high positive phenotypic correlation of 0.999 with unit surface shell weight. This disagrees with the findings of Sezer (2007). Since egg weight was positively correlated with unit surface shell weight and shell weight, and shell weight correlated positively with shell thickness, egg weight can be said to have an indirect relationship with the eggshell quality.

The correlation between egg length and egg width (0.407) was significantly positive because as the egg elongates it broadens as well. There was also a statistically significant but negative phenotypic correlation ($p<0.0 01$) was obtained between shape index and egg length (-0.788). Similar results were reported by Ozcelic (2002); Kul and Seker (2004) and Olawumi and Ogunlade (2008). The reason that may be advanced for this negative relationship is the fact that egg length is the denominating factor in estimating shape index according to Pandey *et al.* (1986). Thus increase in egg length will eventually reduce the value of the shape index.These observations also agrees with the reports of Choprakarn *et al*. (1998).

Egg width showed significant positive correlation with shape index. This is because shape index is directly related to egg width. These results indicate that the size of an egg is limited by its width than by its length. The reason for this observation could be as a result of the denser part of the egg occupying the width area which translates to heavier weight for the egg. Thus the heavier the egg the broader or more rounded it becomes (Pandey *et al*., 1986).

In this study, a significant positive phenotypic correlation ($P<0.1$) of 0.169 was observed between the shape index and shell ratio and this indicates the possibility of improving shell quality with rounder eggs and this explains the evolutionary consequence of egg shape. Richards and Staley (1967) reported that shape index had a significant effect on the variation of crushing strength. Therefore shape index becomes an important factor in the determination of eggshell quality in Cobb 500 breeder eggs

The statistically significant positive phenotypic correlation value of 0.977 observed between shell weight and shell ratio in this study is consistent with the findings (0.65) of Kul and Seker (2004) and (0.82) Olawumi and Ounlade (2008). This means that with all things being equal as shell weight increases the ratio of shell to egg weight will increase.

There was a significant ($p<0.05$) positive phenotypic correlation of 0.132 between the shape index and shell weight which means that the shape index could be considered a good estimator of the shell weight. Contrary to this Kul and Seker (2004) found a statistically significant but negative phenotypic correlation value of -0.25 between shape index and shell weight. Olawumi and Ogunlade (2008) reported a positive but non significant phenotypic correlation of 0.12 between eggshell weight and shape index.

The findings of this study revealed a statistically non significant ($p>0.05$) but positive correlation between shape index and shell thickness and this is consistent with the findings of Olawumi and Ogunlade (2008) who reported a value of 0.16 ($p> 0.01$). Kul and Seker (2004) reported a negative but non significant phenotypic correlation between shape index and the shell thickness. However, Yannakopoulos and Tserveni-Gousi (1986) stated that shape index could be used as criterion for determining the stiffness (resistant to pressure) of the eggshell.

4.2.2 Phenotypic correlation between internal quality traits

The phenotypic correlation values of the internal quality traits are as shown in **Table 9** below. A statistically significant ($p<0.01$) positive correlation value of 0.58 was found between yolk weight and yolk diameter and this agrees with the findings of Kul and Seker (2004) and

Olawumi and Ogunlade (2008) who reported correlation values of 0.55 and 0.6 respectively between yolk weight and yolk diameter. These observations indicate that as the weight of the yolk rises the greater its diameter.

There was a statistically significant ($p<0.01$) but negative phenotypic correlation of -0.384 between yolk weight and the albumen ratio which agrees with the findings of Kul and Seker (2004) and Olawumi and Ogunlade (2008). The implication of this observation is that as the weight of the yolk increases the ratio of albumen weight to total egg weight is reduced.

A statistically significant ($p<0.01$) positive phenotypic correlation value of 0.642 was found between yolk height and Haugh unit, so that with an improvement in Haugh unit which is a function of the height of the inner thick albumen, the yolk height increases although this requires a genetic correlation analysis in order for this assertion to be made.

Statistically significant ($p<0.01$) negative phenotypic correlations of -0.571 and -0.568, were obtained for yolk ratio and albumen weight; and yolk ratio and albumen ratio respectively; whereas statistically significant ($p<0.01$) positive phenotypic correlation values of 0.684 and 0.466 were obtained for the yolk height and albumen height; and yolk height and albumen weight. These results indicated that as the yolk height and diameter increased the albumen height also increased. However, the albumen ratio has an inverse relationship to the yolk ratio so that as one increases the other decreases

Table: 9. The phenotypic correlations between internal egg quality traits

Internal egg Quality traits	Albumen height	Albumen weight	Albumen ratio	Haugh Unit	Yolk Diameter	Yolk Height	Yolk Weight	Yolk Index	Yolk Ratio
Albumen height	1.00	0.578**	0.490**	0.976**	0.007	0.684**	-0.111*	0.619*	-0.391**
Albumen weight		1.00	0.873**	0.526**	-0.064	0.466**	-0.114*	0.441**	-0.571**
Albumen ratio			1.00	0.506**	-0.256**	0.369**	-0.384**	0.427**	-0.568**
Haugh unit				1.00	-0.058	0.642**	-0.171**	0.606**	-0.373**
Yolk Diameter					1.00	0.087	0.581**	-0.295**	0.443**
Yolk height						1.00	0.001	0.876	-0.246**
Yolk Weight							1.00	-0.215**	-0.791**
Yolk Index								1.00	-0.393**
Yolk Ratio									1.00

*:$p<0.05$, **: $p<0.01$

A statistically significant ($p<0.01$) but negative phenotypic correlation value of -0.171 was obtained between the Haugh unit and the yolk weight, whereas a statistically non- significant negative phenotypic correlation value of -0.064 was obtained for yolk diameter and albumen weight. This was however contrary to the statistically significant phenotypic correlation value of 0.21 in layers obtained by Olawumi and Ogunlade (2008) and 0.40 in quails by Kul and Sekar (2004). The difference between the findings of this research and that of Olawumi and ogunlade (2008) could be as a result of differences in genotype since the yolk: albumen ratio is higher in eggs from broiler breeder hens than in eggs from commercial laying hens as observed by Dutta and Islam (2010). This was also supported by Ho *et al*. (2010) who reported that albumen mass and shell mass of broiler parents were significantly lower than that of layers whereas yolk mass of broiler parents was found to be higher than that of the layer.

Statistically significant (P<0.0l) phenotypic correlation values of 0.976 and 0.578 were found between the albumen height and the Haugh unit, and albumen height and albumen weight respectively. The Haugh unit is a measure of appearance of the albumen of freshly broken egg. It is also the logarithm of the height of the inner thick albumen adjusted for egg weight. Therefore an increase in the height of the albumen will automatically increase the Haugh unit. It also means that as the weight of the albumen increases so does the albumen height.

The significant positive (p<0.01) phenotypic correlation found amongst albumen weight, albumen ratio and albumen height, which are the parameters associated with albumen quality (Ozcelic, 2002) and with estimating the Haugh unit implies that as these parameters increase the Haugh unit increase as well. The Haugh unit also declines more rapidly than does the actual albumen height because of the over compensation for egg weight in the Haugh unit calculation. Correlation coefficients between Haugh unit, albumen height, and the log of the albumen height were very high. When comparing eggs from diverse groups of hens, the Haugh unit correction for egg weight will likely introduce more error than it will eliminate (Silversides and Scott, 2001). The Haugh unit is one of the internal quality traits of the egg and an important criterion for determining the internal quality traits of the egg. Therefore any improvement in the egg albumen will influence the Haugh unit (Ihekoronye and Nkoddy, 1985).

The significant positive correlation of 0.98 between albumen height and Haugh units obtained in this research supports the findings of other researchers like Oluwami and Ogunlade (2008), Kul and Sekar (2004), Akbas *et al*. (1996) and Ozcelic (2002) who reported values as 0.98, 0.95, 0.97 and 0.97 respectively. This implies that as the albumen height improves the Haugh unit also gets better. This was also supported by Silversides and Scott (2001) who also obtained significant positive phenotypic correlation between Haugh unit and albumen height. He however stated that the Haugh unit declines more rapidly than does the actual albumen height because of the over compensation for egg weight in the Haugh unit calculation. .

4.3.3 Phenotypic correlation between internal and external quality traits

The phenotypic correlation between the internal and external quality traits of eggs are shown in **Table 10**. The results of this research relating to the phenotypic correlation between the internal and external quality traits of the egg indicates a significant ($p<0.01$) but negative phenotypic correlation between egg weight and the yolk ratio.

However, there were significant ($P<0.01$) positive correlations between egg weight and albumen weight, albumen height, albumen ratio, haugh unit, yolk diameter, yolk height, yolk weight, and yolk index. These were in agreement with the findings of Ozcelic (2002) and Isam and Dutta (2010). These mean that as the weight of the egg increases, the albumen weight and yolk weight also increase. However the increase in weight of the albumen overshadows that of the weight of the yolk, the yolk ratio then decreases with an increase in the weight of the egg.

There is also an indication that as the egg weight increases the heights of both the albumen and yolk also increase, the Haugh unit which is based on the albumen height also gets better. Benton *et al*. (1997) were of the view that albumen height classified as high quality trait in eggs has been found to reduce hatchability and increase the length of incubation. High Haugh unit values, though a setback to breeding eggs in terms of hatchability, are an important indication of freshness in commercial layers.

Table 10. Phenotypic correlation between external and internal quality traits of the egg

	External quality traits							
Internal egg quality traits	Egg Weight	Egg Width	Egg Length	Shape index	Shell Thick-ness	Unit surface shell weight	Shell weight	Shell Ratio
Albumen height	0.435**	0.196**	0.364**	-0.264**	0.030	0.433**	-0.236**	-0.319**
Albumen weight	0.712**	0.352**	0.430**	-0.237**	-0.028	0.711**	-0.520**	-0.641**
Albumen ratio	0.282**	0.149**	0.267**	-0206**	0.034	0.282**	-0.739**	-0.786**
Haugh unit	0.310**	0.130**	0.325**	-0.267**	0.023	0.307**	-0.286**	-0.349**
Yolk Diameter	0.299**	0.192**	0.073	0.061	0.096	0.231**	-0.001	-0.036
Yolk height	0.385**	0.139**	0.305**	-0.240**	0.086	0.385 **	-0.22**	-0.286**
Yolk Weight	0.271**	0.345**	0.209**	0.009	0.003	0.319**	-0.069	-0.116*
Yolk Index	0.271**	0.065**	0.244**	-0.226**	0.066	0.27**	-0.178	-0.225**
Yolk Ratio	-0.318**	0.053	-0.095	0.138*	0.004	-0.322**	-0.098	-0.032

*:p<0.05, **: p<0.01

According to the results obtained in this research, almost all internal quality traits of the egg correlated positively at (p<0.01) significant levels with egg weight. This is consistent with the findings of Wolanski *et al*. (2006) who described strong and positive correlations between egg weight and albumen weight (0.84), and between egg weight and yolk weights (0.48) in broiler breeder eggs. This means that as the weight of the egg increases the albumen weight increases more than the other component of the egg. Therefore large eggs tend to have high albumen ratios than smaller eggs do within strains.

Negative phenotypic correlation at (p<0.01) significant levels between the shell weight and albumen height, albumen weight, albumen ratio and yolk height were observed in this study. These observations disagrees with the findings of Olawumi and Ogunlade (2008), whose report revealed a positive phenotypic correlation between eggshell weight the internal quality traits like yolk weight (0.47), yolk height (0.19), yolk diameter (0.26) and albumen weight (0.33) whilst a negative correlation value of -0.33 was obtained between the shell weight and albumen ratio.

Statistical significant negative correlations were observed between the shell ratio and all the internal quality traits, example, albumen weight (-0.64), albumen height (-0.32), albumen ratio (-0.79), yolk height (-0.12), Haugh unit (-0.349) and yolk index-0.023. These results are in agreement with the research findings of Oluwami and Ogunlade (2008) and Ku1 and Sekar (2004). The explanation is that the weight of the internal component of the egg contributes much to the increase in egg weight. Meanwhile increasing the egg weight will result in a reduction in the shell ratio. Therefore an improvement in any of the internal component of the egg will depreciate the proportion of shell weight to total egg weight though genetic correlation is needed to make this conclusion.

There was significant ($p<0.01$) negative phenotypic correlation between shape index and all the internal quality traits except with the yolk diameter (0.06), yolk weight (0.009) which correlated positively but not significant with the shape index. However, the shape index was significantly and positively correlated with yolk ratio. This is as a result of the yolk occupying the width area (Richards and Staley, 1967) which in turn increases the shape index according to the formula: Shape index (%) = [Width (cm) / Height (cm)] * 100 which means that an increase in the width, which also means an increased proportion of yolk, will translate into a higher shape index.

In the finding of Olawumi and Ogunlade (2008) although the shape index was found to be phenotypically negatively correlated with the internal quality traits, it was however non significant. Kul and Seker (2004) also reported statistically negative phenotypic correlation between the shape index and the internal quality traits except with albumin ratio and Haugh unit which were found to be positive and non significantly correlated with the shape index.

There was statistically significant ($p<0.01$) and positive phenotypic correlation between both egg width, egg length and almost all the internal quality traits except yolk ratio. This means that, as the egg length and egg width increased almost all the internal quality traits of the egg also increased. This could be due to the fact that both factors (egg width and egg length) determine the volume and holding capacity of the egg and consequently the weight of the egg. Therefore as the weight of the egg increased and both egg width and egg length increased all the internal quality traits of the egg except yolk ratio which had no significant correlations with both the egg width and egg length. There was no significant phenotypic correlation between the shell thickness and any of the internal quality traits of the eggs used in this research. This implies that the shell thickness of the Cobb500 hatching eggs used in this research is not dependent on any of the internal quality traits of the egg.

There was significant ($0.05<p<0.01$) positive phenotypic correlation between the unit shell surface weight and all the internal quality trait of the egg except the yolk ratio which correlated significantly negative with the unit shell surface weight of the eggs used in this research. The findings of this research agree with the findings of Olawumi and Ogunlade, 2008. As the formula for the unit shell surface weight stands according to Stadelman (1986) that is, Unit shell surface weight= Egg weight/Egg surface area means the egg weight is directly proportional to the unit shell surface weight, therefore increase in any of the internal quality traits that would cause an increase in the egg weight would also increase the unit surface shell weight.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The overall mean egg weight obtained in this research differed slightly from the findings of other researchers like Wolanski *et al*, (2007) who reported 63.4g to 66g a little higher, Islam and Dutta, (2010), 46g with Cobb500 which was much lower. However the findings of Romero *et al*, (2009), 60g to 62g for Ross708 was very close to the findings of this research.

This study revealed that as the egg weight increased, all the external quality traits increased except the shape index and the shell ratio. The present research indicated that egg weight cannot be a good estimator of shell quality (shell weight, and shell thickness) of eggs from Cobb500 broiler breeders. The positive significant correlation between the shape index and shell ratio, which is a more reflective method to evaluate shell quality than the absolute shell weight as was detected in this research, indicates the possibility of improvement in shell quality with rounder eggs.

Haugh unit, which is an important index in the determination of internal egg quality, was highly influenced by both the yolk height and albumen height. Thus as the yolk height increases the albumen height also increases as well as the Haugh unit.

In addition, it was found that all the internal quality traits of the egg, except the yolk ratio, correlates positively at statistically significant levels with the egg weight, egg length and egg width. Moreover, all the internal quality traits were found to correlate negatively with both shell weight and shell ratio, implying that any increase that occur in any of the internal quality traits of these eggs will result in compromised shell quality.

5.2 Recommendations

1. With the exception of the shape index, shell ratio and the yolk ratio the egg weight correlates positively and significantly with all the external and internal quality traits of the Cobb 500 hatching eggs used in this research. It is obvious that these traits are beneficial egg quality traits and of immense importance to poultry breeding industries (Islam *et al*, 2001). Thus egg weight is one of the traits which influence egg quality and reproductive fitness of the Cobb 500 chicken parents. It is therefore recommended that the breeders' selection programmes should be geared towards the weight of the egg which is influenced by the weight of its constituents.

2. The effect of hens' age, weight and period of storage on the quality characteristics of eggs must be considered in a future research on internal and external quality traits of eggs.

3. Research into the heritability of these traits would be very important since this would give an understanding of how these traits would change from one generation to the other in response to selection.

5. Further research must be conducted on estimating the genetic correlation among the quality traits to predict the potential progress for both commercial and breeder eggs.

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