EFFECTS OF DIFFERENT STORAGE METHODS ON EGG QUALITY INDICES DURING THE HOT AND COLD SEASONS

BY

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DECLARATION

I declare that the work in this thesis entitled **"EFFECTS OF DIFFERENT STORAGE METHODS ON EGG QUALITY INDICES DURING THE COLD AND HOT SEASONS"** has been performed by me in the Department of Animal Science under the supervision of Professor I.I Dafwang and Dr. T.S Olugbemi. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree at any University.

____________________________ ________________________

BubaWahe **Date**

CERTIFICATION

This thesis entitled **"EFFECTS OF DIFFERENT STORAGE METHODS ON EGG QUALITY INDICES DURING THE COLD AND HOT SEASONS"** by **BubaWahe**, meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this research work to my father, MrBubaZiraKwaya who always encouraged me to study and to the memory of my late mother, Francisca.

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ABSTRACT

A total of 1,944 poultry eggs were used for this study to determine the effect of storage methods on egg quality indices during the cold (Dec-Jan) and hot (March-April) seasons. The different storage methods used were Refrigeration (R), Room Temperature (RT), Oiling (O), Covering with Leaves (CWL) and Earthen Pot (EP) storage. The average temperature for the hot and cold seasons, were 32^0C and 21^0C respectively while the relative humidity were 36.84% and 17.75% respectively. The results obtained showed that egg quality indices were significantly ($P<0.05$) affected by the different storage methods and season. Results also showed that Colony forming unit (Cfu/ml) also increased especially for RT storage with the hot season having $7.5x10^{-2}$ and cold season $4.5x10^{-2}$cfu/ml. Refrigerated eggs had the least cfu of $3.0x10^{-2}$ for both seasons. A significant ($P<0.05$) decrease was recorded for egg weight for all the storage methods for both seasons. Oiled eggs had weight losses of 1.66g and 1.75g for the cold and hot seasons respectively and room temperature storage had rapid weight losses of 5.21g and 6.23g for cold and hot seasons respectively which indicate deterioration in quality. The ease at which egg peels was also affected by the different storage methods and season; Oiling method ranked (1) which is difficult to peel for 6 and 15 days during the hot and cold seasons whereas Room temperature storage was difficult to peel for 6 days for both hot and cold seasons. Eggs that were stored in the R, O, and EP were able to keep the shelf life of eggs for a longer period compared to RT and CWL storage which lost quality rapidly after extended storage. The duration at which eggs stored under the different strorage methods during the cold season and still maintain a high quality (Haugh Unit) were R:36 days, RT: 18 days, O:27 days, CWL: 18 days and EP: 24 days while for the hot season the duration were R:36 days, RT: 9 days, O:21 days, CWL: 9 days and EP: 21days. It is concluded that in the absence of refrigeration storage or consistent power supply, the use of oiling method of storage or earthen pots kept in the shade is most recommended. It is recommended that further studies should be carried out on the economic analysis and acceptability of oiling and earthen pot storage.

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CHAPTER ONE

1.0 Introduction

Eggs are important components of the human diet, consumed by people throughout the world. They are versatile and wholesome and they have a natural balance of essential nutrients (MAFF, 2006). Egg production has been, and continues to be a major agricultural industry in many countries. In 1999, total egg production in the USA, for example, was almost seven billion dozen with China accounting for 40% of the world production; (USDA, 2000). Poultry production in Nigeria is spreading and increasing, with many households having backyard poultry farms. Figures for egg consumption are not available; however, it is a popular food component in Nigeria.

Egg gluts occur from time to time, during which many poultry farmers may incur enormous economic losses including those attributable to spoiled unsold eggs. Similarly, eggs also spoil in homes due to inability to refrigerate the eggs as a result of electricity failure which is common in Nigeria.

Deterioration in egg quality is attributed to moisture loss and a decline in interior egg quality during extended storage (Wong *et al.,* 1996). The shelf life of shell eggs, during which they are of good quality and safe to consume, is a function of carbon dioxide content (Keener *et al.,* 2001). Factors associated with decline in quality are storage time, temperature, humidity and handling (Samli*et al.,* 2005).

Eggs with Intact shells are relatively free of bacteria, and this is because egg shells and their membranes provide a barrier against bacterial invasion. The main risk of massive bacterial contamination occurs if the egg shell is broken, cracked or if there is excreta contamination of the shell (Rose, 1997).

Poor shell quality, albumen quality and yolk quality result in downgrading. Maintaining good egg quality from producer to consumer is one of the major problems facing those engaged in marketing eggs. Proper attention to production, distribution and point-of-sale phases are of vital importance in maintaining egg quality. Temperature, humidity, storage method and storage time can all have adverse effects on interior egg quality (Samli*et al.,* 2005)

Egg quality is composed of those characteristics of an egg that affects its acceptability to consumers such as cleanliness, shell quality, freshness, and size, (Stadelman and Coterill 1995; Song *et al.,* 2000).

The egg is a very perishable food product, which could lose its quality rapidly during the period between when it is laid and consumption. Eggs provide a unique and well balanced source of protein which contains all the essential amino acids in sufficient amounts and proportion to maintain life and support growth even when used as a sole source of food protein (Ricketts, 1981).

Proper storage of eggs is essential to preserve quality and cooking characteristics. Poor storage conditions can reduce egg grade within a few days. The principal degrading factors are high storage temperature and dehydration. Improper storage is reported to produce some observed changes: a reduction in the viscosity of the albumen, an enlargement yolk that breaks easily when the shell is broken, enlargement of the air cell, and absorption of off odours and off-flavours if stored near pungent foods (Mohammed, 2011). . Since storage environment influence the quality of eggs, methods like lowering temperature and modified atmosphere packaging in inert gases, such as carbon dioxide and nitrogen refrigeration have been recommended. The physical appearance of an egg makes the first impression upon the consumer. If the product does not meet perceived expectations, consumer confidence diminishes (Jones *et al*., 2005).

Unlike external quality, the internal quality of eggs starts to decline as soon as they are laid by hens. Although factors associated with the management and feeding of hens can play a role in internal egg quality, egg handling and storage practices also have a significant impact on the quality of eggs reaching consumers. Albumen quality is not only an important indicator of egg freshness; it is also significant for the egg processing industry. Albumen quality is a standard measure of egg quality, and it is influenced by genetic factors (Jin *et al.,* 2011) and environmental factors such as storage temperature and time (Samli*et al.,* 2005).

The high environmental temperature in the tropics pose special problems to the poultry industry in general, and egg production in particular (Dafwang, 1987).The hottest time of the year in most parts of Nigeria is from March to May. During such periods egg production often declines. In extreme cases, birds may die from heat stress. Apart from the effect on egg production and quality, high environmental temperatures causes egg storage problems. Several methods of altering the environmental conditions of the egg have been used to prolong its storage life. Refrigeration and freezing of egg and egg products are widely practiced. However, these methods are expensive and require constant electric power supply, hence are often not suitable in developing countries generaly, and particularly in the rural areas (Samli*et al.,* 2005).

To retard the deteriorative changes in the internal qualities of eggs, various shell treatments such as coating with vegetable and mineral oils, water glass and lime sealing have been suggested. Oil coating of the shell has been documented as a method of preserving quality and is an accepted practice. In coating, the shell pores are sealed reducing evaporation and carbon dioxide escape, thus much of the original carbon dioxide is retained and albumen pH increases less rapidly. (Obanu and Mpieri, 1984).

The aim of this study is to find means of improving the shelf life of shell eggs produced and stored under high ambient temperature and unreliable electric power regimes.

OBJECTIVES

The objectives of the study were to determine:

1. The effect of storage method on egg quality indices.
2. The effect of season on egg quality indices.
3. Effect of storage method on microbial load of eggs
4. Effect of storage methods on ease of peeling of boiled eggs.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Importance of the egg

In recent years, poultry industry has occupied a leading role among agricultural industries in many parts of the world. Africa, Asia and South America show the greatest increase in egg production, 35.2%, 46.9% and 32.5% respectively, while North and Central America, Europe and Oceanic show very little increase and in some cases a decrease in egg production (USDA, 2000). During the past decade, the production of eggs continued to increase rapidly in the underdeveloped regions, which include most of the hot regions of the world. With the exception of a few countries like Saudi Arabia and Israel, the hot regions of the world have probably the greatest potential for further growth since the level of consumption is still very low. The poultry industry is highly developed in South Africa and has seen a great deal of development in other African countries during the past two decades (Daghir, 1995).

Eggs are among the highest in quality of human foods. Eggs are beginning to make a substantial contribution in relieving the protein insufficiency in many African countries. MAFF (2006) reported that only 44 eggs were produced on the African continent per person per year. The top egg-producing countries of Africa (Nigeria, South Africa, Egypt and Algeria) have increased their production from 4.2 billion in 1960 to 16.5 billion in 1990 (Saxena, 1992). Every day, over 26 million eggs are produced in the UK (MAFF, 2006).

2.2 Structure of the egg

The egg is a complex entity having four main parts; these are the shell, shell membranes albumen and yolk. The dry matter of a domestic fowl's egg contains approximately 64% albumen, 27% yolk, 9% chalazae and 0.75% shell membrane (Rose, 1997).

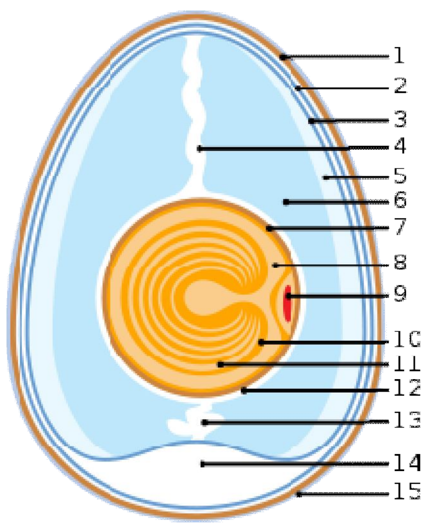

Plate 2.1: Diagram of a chicken egg

1. Egg shell
2. Outer membrane
3. Inner membrane
4. Chalaza
5. Exterior albumen
6. Middle albumen
7. Vitelline membrane
8. Nucleus of pander
9. Germinal disc (nucleus)
10. Yellow yolk
11. White yolk
12. Internal albumen
13. Chalaza
14. Air cell
15. Cuticle

2.2.1 The Shell

The egg has an outer hard covering referred to as the shell; this accounts for about 11% of the total egg weight. It functions as a physical barrier to protect the contents of the egg, and also mediates gaseous exchange of the developing embryo through small pores present throughout the shell (Oluyemi and Roberts, 1992). The shell is also covered with a waxy cuticle which partially blocks the pores to prevent excessive evaporation of moisture from the egg and also physically blocks the entrance of microorganism into the egg. The cuticle is bacteriostatic in nature (Juliet, 2004). The cuticle is the outermost part of the shell and aside its bacteriostatic nature, it also gives the egg its characteristic bloom or shine (MAFF, 2006). Shell colour comes from pigment in the outer layer of the shell. The shell colour is primarily a breed characteristic, although there is often difference among individual hens in particular flock even when all are of the same breed and variety (Jacob *et al.,* 2000). Breeds with white ear lobes ordinarily lay white eggs, while breeds with red ear lobes ordinarily lay brown eggs. The local chicken has both white and brown eggers. Egg shell colour varies greatly for the guinea fowl egg, ranging from white to light brown, motled and tinted. The local duck and scavenging local chicken both have white and tinted egg layers (Pousga and Ogle, 2005). Egg shell texture can be assessed as either rough or smooth (Ikeobi*et al.,* 1996). An egg shell that is smooth is preferred, since rough shelled eggs fracture more easily and have poor appearance (Jacob *et al.,* 2000).

Some eggs may have rough, pimpled appearance. The pimples which are calcium deposit cause the shell to be distorted in appearance, this defect may be partly hereditary. Shell texture deteriorates as the bird gets older. Mineral nutrition also plays a vital role in determining the egg texture. High phosphorous and low calcium levels causes ridging and distortion of the shell (Thear, 1990).

2.2.2 Albumen

The albumen surrounds the yolk and act as a shock absorber. (Rose, 1997). It is rich in protein and vitamins and contains substances which protect the egg from micro-organisms which may have entered through the shell. In a freshly laid, good quality egg, alternating layers of thick and thin albumen are clearly visible. The innermost layer of thick albumen (the chalaziferous layer) is extended at two opposite points, forming the white, fibrous chalazae which are anchored in the outer thick albumen. The structure of the albumen is designed to provide support and protection to the yolk, holding it centrally inside the egg (MAFF, 2006).

2.2.3 Yolk

The yolk is the yellowish spherical structure enveloped in the albumen (Jones, 2005). The yolk is easily identified by its bright, yellow color both when cooked and raw. It is spherical, although when the egg is broken out raw it tends to flatten out (Oluyemi and Roberts, 1992). The yolk consists of fats, vitamins and minerals together with about half of the egg's total protein content. A transparent barrier called the vitalline membrane surrounds the yolk and prevents the yolk content leaking into the albumen. On the surface of the yolk, under the vitalline membrane is the germ cell (or germinal disc), which is the site of cell division if the egg is fertile (MAFF, 2006). The colour of the yolk varies and this is influenced by the laying hen's diet but the colour of the yolk has no connection with food value (MAFF, 2006).

2.3 Egg Size and egg weight

There appears to be a general and direct relationship between body size of birds and the size of eggs laid. Birds with large body size lay large eggs and vice-versa (Singh *et* *al.,*1992). Different species of poultry and strains within species all have their characteristic egg weight (Rose, 1997). Egg weight is determined by the breed or strain, the age of the hen, body weight, and composition of the feed. (Particularly the energy and crude protein content), the ambient temperature and lighting schedule (Ketelaars and Saxena 1992). Eggs are graded according to shell colour and texture, size, shape, cleanliness and freedom from cracks and other defects (Aduku, 1993).

2.4 Egg Shape

There are great variations in shape of avian eggs. Eggs laid by the same species resemble but may not be identical. Some eggs are truly oval; others may be spherical or elongated or equally pointed on either side (Rose, 1997). Breed factors are generally responsible for the diversities in the shape of normal eggs. Shape can also be influenced by diseases. The normal poultry egg is elliptical in shape (Jacob *et al.,* 2000). Thin, misshaped, rough, ridged or soft shelled eggs could be caused by constantly high temperatures, low calcium intake, sulfa drugs, respiratory disease (e.g Newcastle), bronchitis and high salt(Nacl) content in feed, fright and poisonous drugs (Beyer, 2005).

2.5 Egg Colour

Egg colour often has economic importance as there are local prejudices in favour or against certain traits. It may be white, yellow or different shades of brown in eggs of domestic chickens (Singh *et al.,* 1993). The colour of the egg is determined by genetic factors. In general chickens with white ear lobes lay white eggs while those with brown ear lobes lay brown eggs. Egg shell colour has no effect on nutritional value.

2.6 Nutritive value of eggs

The nutrient profile of the egg is given in table 2.1. Eggs are a concentrated source of nutrients compared to the amount of energy they supply. The yolk is particularly rich in nutrients. Yolk supplies approximately 50% of the protein in the egg and nearly all the fat (Singh *et al.,* 1992).

2.6.1 Egg proteins and energy

Egg protein is of high quality and easily digestible. The levels of amino acids are similar to the balance of amino acid needed by humans. The fat within egg is emulsified and highly digestible (Rose, 1997). Eggs contain high levels of unsaturated fatty acids although this may be affected by the diet of the birds (Oluyemi and Roberts, 1992). The mineral compositions of the edible parts of eggs are relatively high. Eggs are particularly rich in iron and phosphorous. Diets of the laying birds can also alter the mineral composition of eggs (MAFF, 2006). The average egg provides approximately 647 kilojoules of energy, of which 80% comes from the yolk (USDA, 2000).

2.6.2 Vitamins

Eggs are an important vehicle to complement the essential vitamin supply to the human population. Eggs contains all vitamins except vitamin C, they are particularly rich in the fat soluble vitamins i.e. Vitamin A, D, E and K (Rose, 1997).

2.6.3 Minerals

Eggs are a good source of iron and phosphorus and also supply calcium, copper, iodine, magnesium, manganese, potassium, sodium, zinc, chloride and sulphur. All these minerals are present as organic chelates, highly bioavailable, in the edible part of the egg. (USDA, 2000).

Table 2.1: Nutrient value of Chicken Eggs per 100g

Nutrient	Value	Nutrient	Value
Carbohydrates	1.12 g	Glycine	0.423 g
Fat	10.6 g	Proline	0.501 g
Protein	12.6 g	Serine	0.936 g
Tryptophan	0.153 g	Water	75 g
Threonine	0.604 g	Vitamin A	140 µg
Isoleucine	0.686 g	Thiamine (Vit. B_1)	0.066 mg
Leucine	1.075 g	Riboflavin (Vit. B_2)	0.5 mg
Lysine	0.904 g	Pantothenic acid(B_5)	1.4 mg
Methionine	0.392 g	Folate(Vit. B_9)	44 µg
Cystine	0.292 g	Choline	225 mg
Phenylalanine	0.668 g	Vitamin D	87 IU
Tyrosine	0.513 g	Calcium	50 mg
Valine	0.767 g	Iron	1.2 mg
Arginine	0.755 g	Magnesium	10 mg
Histidine	0.298 g	Phosphorus	172 mg
Alanine	0.700 g	Potassium	126 mg
Aspartic acid	1.264 g	Zinc	1.0 mg
Glutamic acid	1.644 g	Cholesterol	424 mg

Source: USDA Nutrient Data Base (2000)

2.7 Egg Quality

Egg quality is the sum total of the characteristics of an egg which appeal to the consumer. Measurement of these characteristics is a prerequisite for their improvement through research. Some important egg quality characteristics are; colour of shell, shell porosity, shell strength, albumen conditions, yolk shape and colour, nutritional value, flavour, cleanliness, presence of meat and blood spots etc. (Rose, 1997). The quality of an egg is influenced by many factors which can be divided into two broad categories; those that come into play before the egg is laid and those that take effect after the egg has been laid (Oluyemi and Roberts, 1992).

2.7.1 Measures of Egg Quality

Quality in eggs with reference to food value or marked desirability is measured by

(i) external appearance

(ii) by odour and flavour

(iii) Physical characteristics of components of the opened egg (Rose, 1997).

The external quality of an egg may be assessed by size, shape, shell colour and texture, cleanliness and uniformity of eggs within a given sample or lot (Mertens, 2009).

2.8 Egg Handling

On the farm, eggs should be collected regularly and kept in cool and ventilated stores. Dirty eggs should be cleaned with abrasive materials in preference to washing. If it is necessary to wash, the water temperature should be 38-43^{o}C and change every few minutes. Washed eggs should not be stored (Oluyemi and Roberts, 1992).

2.9 Cleaning of eggs

Dirty eggs are covered with bacteria that will cause spoilage if they penetrate the eggs (Singh *et al.,* 1993). Slightly dirty eggs can be dry cleaned easily with the help of cloth or fine sand paper which can be used to scratch out dirty spots or stains (Smith and Leclecq, 1990). Wet washing of dirty eggs can also be carried out, and is the most effective and simplest way to provide shell eggs with the appearance preferred by consumers. (Oluyemi and Roberts, 1992). Most eggs are clean when they are laid but can become contaminated with manure or other foreign materials. Egg with manure or adhering material is unattractive in the appearance and cause the egg to be downgraded (Jacob *et al.,* 2000). Every effort should be made to produce clean eggs by maintaining a high standard of management (Thear, 1990).

2.10 Preservation of Eggs

Broken eggs may be stored in liquid or dry form (Frazier and Westhoff, 1995). Liquid eggs are usually sorted into plain yolk, salted or sugared yolk and albumen. They are normally frozen and held in this form until used. Liquid eggs are shipped in bulk to drying and processing plants in refrigerated trucks (Nesheim*et al.,* 1979). Eggs may also be prepared and kept dry. The evaporation process usually involves the use of high pressure steam at 250-350^{o}F (Nesheim*et al.,* 1979).

2.10.1Lowering of temperature

Chilling using a refrigerator or cooling in clay pots is the most common method of preservation of eggs. Others include oiling, storage under inert gases, additionof chemicals, irradiation and pasteurization (Frazier and Westhoff, 1995). Eggs should be cooled as promptly as it is practicable after production and held at a temperature and a relative humidity that depends upon the anticipated duration of storage (Hou*et al*., 2004; Keener *et al.,* 2006).

Locally produced, clay pots buried in the ground in a cool area, filled with eggs and covered tightly has been reported by Frazier and Westhoof (1995).

2.10.2 Shell coating

Oiling has also been reported by Semih and Yasar (2004) as an effective method. The coating method of the eggshell with oil was first used by Dutch farmers as early as 1807, and it was reported that coating the egg with mineral oil greatly improved the shelf-life of the eggs (Okoli and Udedibie 2000). Raji *et al.* (2009) suggested that coating the eggs several hours after laying is most effective, and Lee(2000) and Xie *et al*. (2002) reported that the lowering ambient temperature and maintenance of adequate humidity are necessary after oil treatment for maximum effectiveness.

Tanabe and Ogawa (1979) studied the effects of washing and coating materials on interior quality of chicken eggs, and reported that coating with vegetable oil or mineral oil was more effective than coating with sucrose-fatty acid ester emulsion to keep internal quality of eggs for a 13 day period. Wong *et al.* (1996) studied the effect of coating with oil on the weight loss and the interior quality during storage. Oiling slowed down the decline of Haugh units and increase in albumen pH in eggs stored at $28^{o}C$ and $12^{o}C$ (Jin *et al*., 2011). Coating also improved shell breaking strength to certain extent by generating a protective barrier (Alleoni and Antunes, 2004). Oil coating checks the loss of moisture and carbon dioxide during storage and minimizes the risk of uptake of odour and penetration of microorganisms and also inhibits mould growth. The oil used for sealing must be odourless and colourless (Okoli and Udedibie, 2000). The use of water glass (sodium silicate) as a chemical method of egg storage has been reported by Frazier and Westhoof, 1995. Limewater has also been discovered to be an effective egg preservation method (Keener *et al.,* 2001). To preserve the eggs in lime water, one pound of salt is dissolved in one quarter of finely slaked lime in 3 gallons of water, the solution is stirred at frequent intervals for a day or two, and the liquid is allowed to settle, the eggs are then placed in kegs with their pointed ends turned down, filling the receptacles to within a few inches of the top. The clear lime water is poured over the eggs arranged, allowing it to rise an inch or two above the top layer, the vessel is then kept in a cool place where the temperature will not exceed 50 degrees Fahrenheit. Eggs treated with lime water will keep for at least 6 – 8 months.

2.10.3 Irradiation

A more recently discovered method is the use of ionizing radiation, such as ultra-violet light, to render pathogens inactive or kill them. (Sheldon and Schuman, 1996).

2.10.4 Pasteurization of Eggs

Pasteurization of eggs is a process which is intended to destroy harmful microorganisms, specifically *Salmonellaenteritidis* that may be present on or in the egg (USDA, 2000). Pasteurization is done by immersing eggs in hot water for a specified duration and temperature, the optimum time and temperature is reported as 62.5^oC for 2 minutes (Singh *et al.,* 1992). The keeping quality of thick albumen has been found to improve with this heat treatment.

2.11 Quality Control

This is the application of the knowledge of the manufacturing, marketing and distribution of a product with the optimum level of quality. It assures product conformity, wholesomeness, reliability and quality assurance. Quality assurance itself is a design, a plan established in order to ensure that quality, as defined, is maintained within specific limits (MAFF, 2006).

2.12 Grading

Grading is a form of quality control used to categorize a variable commodity or product into a number of classes. The United States Department of Agriculture (USDA) standards for quality of individual shell eggs were developed on the basis of both interior and exterior quality factors. Commercially, eggs are graded simultaneously for exterior and interior quality.

Eggs which do not meet certain minimum requirements can only be sold for human consumption if they have been pasteurized (or undergone an equivalent process) and meet specific microbiological criteria. Grading systems for shell eggs may vary from country to country or region to region, however, regardless of the grading or classification system used, shell egg quality and interior quality are important factors in determining egg quality (Chukwuka*et al.,* 2011).

United States Department of Agriculture USDA (2000) has developed a system which has three grades of eggs based on the interior quality of the egg, the appearance and condition of the egg shell (USDA, undated). The USDA egg grading specifications are detailed below. *U.S. Grade AA* eggs have whites that are thick and firm; yolks that are high, round, and practically free from defects, clean, and shells that are free of cracks. Grade AA and Grade *A* eggs are best for frying and poaching where appearance is important, and for any other purpose. U.S. Grade A eggs *have* characteristics of Grade AA eggs except that the whites are "reasonably" firm. This is the quality most often found in stores. U.S. Grade B eggs have whites that may be thinner and yolks that may be wider and flatter than eggs of higher grades. The shells must be without cracks, but may show slight stains. This quality is seldom found in retail stores because they are usually used to make liquid, frozen, and dried egg products.

2.13 External egg quality

Poor eggshell quality has been of major economic concern to commercial egg producers, with estimated annual losses in the USA of around 478 million US dollars (Roland 1994). In Australia in 1998, the impact was of the order of 10 million Australian dollars per year. Information obtained from egg grading facilities indicates that 10% of eggs are downgraded due to egg shell quality problems. Based on values for the UK, Germany and the USA, it has been estimated that the incidence of broken eggs ranges between 6 and 8% (Washburn, 1982). In Mexico in 2005, it was estimated that the egg industry lost between 30 and 35 million US dollars, based on average figures of 2.5% broken eggs and 4% weak shells. These are only losses that occur between laying and packing, not taking into account of further losses in transit to the end consumer (Juliet, 2004).

To maintain consistently good egg shell quality throughout the life of the hen, it is necessary to implement a total quality management programme throughout the egg production cycle. It has always been recognized that birds have the most extraordinary method of obtaining and depositing calcium in the entire animal kingdom. A chicken egg has an average of 2.3 g of calcium in the shell, and almost 25 mg in the yolk (Etches, 1987).

Exterior egg quality is judged on the basis of texture, colour, shape, soundness and cleanliness according (USDA 2000). The shell of each egg should be smooth, clean and free of cracks. The eggs should be uniform in colour, size and shape. There are five major types of shell problems in the egg industry:

1. cracks due to excess pressure;
2. cracks due to thin shells;
3. body-checks;
4. Pimpled or toe holes, and
5. Shell-less eggs (Juliet *et al.,* 2004)

2.13.1 Soundness of the shell

Body checks are eggs with shells that have been cracked during calcification in the hen and have a layer of calcium deposit over the crack(s) before the egg is laid. Some "body checks" are covered by a relative thick layer of calcium before being laid so they are not easily detected unless the eggs are candled. Other bodies' checks are only covered by thin calcium layer before being laid (Jacob *et al.,* 2000). The incidence of body checks will increase if hens are disturbed in the afternoon or early evening just as the egg shell begins to form in the oviduct. It is important, therefore, to keep hen as calm as possible especially during the late afternoon and at night (Jacob *et al.,* 2000).

2.14 Internal egg quality

Internal egg quality involves structural properties, and microbial population of the egg yolk and albumen. The proportions of components for fresh eggs are 32% yolk, 58% albumen and 10% shell (Leeson, 2006).

The egg white consist of four structures; Firstly, the chalaziferous layer or chalazae, immediately surrounding the yolk, accounting for 3% of the white. Next is the inner thin layer, which surrounds the chalazae and accounts for 17% of the white. Third is the firm or thick layer, which provides an envelope or jacket that holds together the inner thin white and the yolk. It adheres to the shell membrane at each end of the egg and accounts for 57% of the albumen. Finally, the outer thin layer lies just inside the shell membranes, except where the thick white is attached to the shell, and accounts for 23% of the egg white (USDA, 2000).

Egg yolk from a newly laid egg is round and firm. As the egg gets older, the yolk absorbs water from the egg white, increasing its size; this stretches andweakens thevitellinemembrane making the yolk flater. As soon as the egg is laid, its internal quality starts to decrease: the longer the storage time, the more the internal quality deteriorates.

In a newly laid egg, the albumen pH lies between 7.6 and 8.5. During storage, the albumen pH increases. After 2 days of storage Jin *et al.,* (2011) found an increase in albumen pH regardless of the storage temperature.

Li-Chan *et al,* (1995) observed that when carbon dioxide loss was prevented by the oiling of the shell, the albumen pH of 8.3 did not change over a 7-day period of storage at 22 °C. In oiled eggs stored at 7 °C, albumen pH dropped from 8.3 to 8.1 in seven days (Li-Chan *et al.,*1995).

Increases in albumen pH are due to CO_2 loss through the shell pores, and depend on dissolved CO_2, bicarbonate ions, carbonate ions and protein equilibrium. Bicarbonate and carbonate ion concentration is affected by the partial CO_2 pressure in the external environment. In newly laid eggs, the yolk pH is in general is close to 6.0; however, during storage it gradually increases to reach 6.4 to 6.9. Egg quality preservation throughout the period of storage, handling and distribution is dependent on constant care from all personnel involved in these activities. The quality of the egg once it is laid cannot be improved, so efforts to maintain its quality must start right at the time it was laid (Scott and Silversides, 2000).

The decrease in internal egg quality once the egg is laid is largely due to the loss of water and CO_2. In consequence, the egg pH is altered, resulting in watery albumen due to changes in the thick albumen protein structure. The cloudy appearance of the albumen with age is also due to the loss in CO2 (Jin *et al.*, 2011).

2.15 Factors affecting quality of eggs

Fresh-laid eggs vary in proportions and viscosity of the thin and thick white. The yolk membrane also varies in strength. These variations are probably due to feed, the season of the year, the period of the laying cycle, and individual genetic characteristics of the hen.Akyurek and Okur, (2009) report that the percentage of firm white is lowered by higher air temperature during the hours immediately after the egg is laid, resulting in an apparent seasonal variation in internal egg quality. The poorer quality of eggs obtained during summer months is attributed to the higher temperature during this season. The finest quality eggs are claimed to be those laid in the spring, which coincides with the time of greatest production.

Solomon (1991) suggested that while pores on the surface of the egg do represent possible points of entry for bacteria, particularly as the cuticle hardens just after oviposition, these are of secondary importance to the structural shell and shell membrane defects that may occur. Structural defects, because of their magnitude, offer a much more likely route for bacteria to enter the egg contents. Bacterial and fungal contamination of eggs usually results in black, red or green rot; the egglooks and smells putrid when broken out of the shell (Wilson, 1990; Beyer, 2005).

Bacterial and fungal contamination of eggs,is enhanced by faecal contamination of the egg, and can be prevented by good management practices, including regular replacement of nesting materials or good cage maintenance as appropriate (Wilson, 1990; Beyer, 2005). Bacterial contamination of the egg contents may also occur as a result of an infection in the oviduct of the hen, and any affected hens should be culled (Coutts and Wilson, 1990). Proper handling and storage of eggs following collection will minimise the opportunity for bacterial or fungal contamination. However, improper washing procedures, high storage temperatures and humidity will increase the incidence of bacterial and fungal contamination (Coutts and Wilson, 1990).

2.16 Changes in eggs with duration of storage

Deterioration of eggs starts from the moment it is laid. The first change which takes place in the egg after it is laid is loss of weight due to evaporation of moisture and loss of small quantity of gases like carbon dioxide (Singh *et al,* 1993). Generally, egg deterioration is brought about by processes such as shrinkage, liquefaction, gaseous exchange, hydrogen ion concentration and bacterial decomposition (Nesheim*et al.,* 1979).

At lay, the egg yolk pH is 7.6 while that of the albumen is 6-6.3. With the loss of carbon dioxide from the egg during storage, the pH rises to 9.0. The pH rise initiates several deteriorative chemical changes in the egg. In Nigeria, storing eggs at room temperature of 25.2^{o}C resulted in maximum pH in 3 to 4 days. There were progressive weekly declines in Haugh unit and in egg weights over a four (4) week period. These changes were alleviated by storage at 18.2-35^{o}C (Oluyemi and Roberts, 1992).

Shrinkage can be caused by the evaporation of moisture from within the egg. The amount of shrinkage is usually measured by the size of air cell as seen in candling. The rapidity with which it progresses depends upon the temperature at which the egg is kept, the humidity of the surrounding air, the rate of ventilation and the porosity of the shell (Nesheim*et al.,* 1979; Rose, 1997).

The most important changes occurring in eggs during deterioration are: (i) the thick white becoming less viscous, gradually changing to a thin watery white. (ii) Water passing from the white to the yolk increasing the size and fluid content of the yolk, thus decreasing the yolk solids. In addition the yolk membrane weakens and, if the weakening progresses far enough it breaks when the shell is opened. (iii) loss of moisture usually occurs. (iv) the egg absorbs foreign or off-odours. (v) with continuous loss of carbon dioxide, the alkalinity of the egg increases.

2.17 Measures andMethods of Determining Egg Quality

2.17.1 Yolk colour

Although, yolk colour is a key factor in any consumer survey relating to egg quality consumer preferences for yolk colour are highly subjective and vary widely from country to country (Okeudo*et al*., 2003). The primary determinant of yolk colour is the xanthophyll (plant pigment) content of the diet consumed (Silversides *et al.,* 2006). It is possible to manipulate the yolk colour of eggs by the addition of natural or synthetic xanthophylls to layer hen feeds. This ability to readily manipulate egg yolk colour can be an advantage in meeting market demands. However, the ease with which yolk colour can be manipulated can lead to unwanted colour changes. For example, the inclusion of higher than recommended levels or incorrect ratios of pigments can lead to orange-red yolks (Silversides *et al.,* 2006).

2.17.2 Yolk firmness

The yolk of a freshly laid egg is round and firm (Okoli and Udedibie, 2000). However, as the egg ages and the vitelline membrane degenerates, water from the albumen moves into the yolk and gives the yolk a flattened shape.

2.17.3 Yolk texture

Rubbery yolks may be caused by severe chilling or freezing of intact eggs, the consumption of crude cottonseed oil or the seeds of some weeds (Jacob *et al.,* 2000).

2.17.4 Albumen Consistency

Albumen quality is measured in terms of Haugh units (HU) calculated from the height of the albumen and the weight of the egg (Haugh, 1993). A minimum HU score for eggs reaching the consumer is 60. However, most eggs leaving the farm should be between 75 and 85 HU (Zaman*et al.,* 2005). Albumen consistency is influenced by:

Age of the hen: HU will decrease with increasing bird age, with HU decreasing by around 1.5 to 2 units (Awosanya*et al*., 1998) for each month in lay. Doyon *et al*. (1986) stated that HU decreases at a fairly constant rate of 0.0458 units per day of lay as the hen ages. Doyon *et al*. (1986) also noted that in an ideal situation, HU should be on average 102 at 20 weeks of age, falling to an average of 74 HU by 78 weeks of age.

Genetics: Strain of bird has also been shown to play a role in albumen consistency, with some strains consistently producing eggs with thin albumen. Rajkumar*et al.* (2009) reported that brown egg layers produced eggs with higher HU, while other authors (Sell *et al*., 1982; Williams, 1992) reported that HU values were more variable within the brown egg layers compared with those that lay white eggs. High producing birds tend to lay eggs with relatively lower amounts of thick albumen and, although this can be influenced by selective breeding.

Age and storage of the egg: As the egg ages, carbon dioxide (CO_2) is lost through the shell, the contents of the egg becomes more alkaline, causing the albumen to become transparent and increasingly watery (Okeudo*et al*., 2003). At higher temperatures, loss of CO_2 is faster and the albumen quality deteriorates faster. Decreasing shed temperatures in the hotter months, combined with regular collection of eggs will help to reduce deterioration of the albumen before collection.

Eggs stored at ambient temperatures and humidity lower than 70% will lose 10-15 HU in a few days from point of lay. By 35 days, these eggs will lose up to 30 HU (Natalie, 2009). Storage of eggs at temperatures of 7-13°C and a humidity of 50-60% will reduce the rate of degeneration of thick albumen proteins and, consequently, egg albumen quality will be maintained for longer (Jones, 2006). Oiling of eggs can also help to reduce CO_2 losses and thus help maintain internal egg quality (Okoli and Udedibie, 2000, 2001; Okeudo*et al*., 2003) but is not a substitute for cool storage.

Vanadium: Henry and Miles (2001) reviewed the effects of vanadium on poultry performance. They noted that poorer albumen quality has been reported from laying hensconsuming as little as 6 ppm. Sell *et al*. (1986) showed that the interior quality, of eggs decreased in two strains of laying hensfed 3 or 6 ppm added vanadium. Duyck*et al*. (1990) fed laying hens10 ppm of vanadium for 30 days. HU from these hens averaged 71 HU after one day of storage (62°F (16.6°C) and 60% Relative Humidity) and 64 after seven days of storage. This was in contrast to the average of 82 and 74 HU after one and seven day's storage, respectively, observed for hens fed the control diet. Henry and Miles (2001) reported that the negative effects of vanadium may be overcome by feeding cottonseed meal**,** ascorbic acid, vitamin E or carotene, although this is dose dependant.

Diseases: Diseases such as Newcastle disease can also cause a decrease in albumen consistency (Jacob *et al*., 2003).

2.17.5 Albumen appearance

Normal albumen is transparent, with a slightly yellow green colour. Discolouration of the albumen may occur if the eggs are stored for an extended time in poor conditions, with the albumen becoming much yellower (Cavanagh and Naqi, 2003). Cyclopropene fatty acids from cottonseed meal and the certain weed seeds (Sell *et al.,* 1986) can cause albumen to turn pink after storage. Green whites are caused by excesses of riboflavin (vitamin B2) in the diet. Cloudy whites may be caused by the oiling of eggs within 6 hours of lay (Silversides *et al.,* 2006).

2.17.6 Candling

External appearance is not an accurate indication of what is to be found inside the shell, and it is therefore customary to make use of candling in order to measure internal quality (Nesheim*et al.,* 1979). The characteristics used in measuring quality during candling are appearance of the shell, air cell, yolk, albumen and germ (Rose, 1997). Eggs that have thin, porous or cracked shells can easily be detected. The air space or air cell is usually at the large end of the egg and can be plainly seen when the egg is candled (Singh *et al.,* 1992). The air cell develops between the two membranes that line the shell and increase in size according to the amount of moisture lost from the egg. A motile air cell that moves freely to any part of the egg indicates staleness and damaged shell membrane, probably resulting from rough handling. (Oluyemi and Roberts, 1992). The yolk of a fresh egg, when candled, can only be seen as a faint shadow. It should remain close to the center of the egg (Zaman*et al.,* 2004).

In an egg of lower quality the yolk moves more freely and casts a darker shadow because it floats nearer to the shell (Abdel-nour, 2008). Most of the differences in appearance have been observed to be due to changes in the white or albumen rather than the change in the yolk. In an egg of top quality the albumen is firm, clear, thick or viscous that the yolk does not move freely in it (Abdel-nour, 2008). High-grade eggs must not show any visible germ developments (Nesheim*et al.,* 1979).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The study was carried out at the Departments of Animal Science and Microbiology of Ahmadu Bello University, Zaria Kaduna State.

3.2 Source of Eggs

Eggs were collected at Rebsons Farm Shika Zaria, Kaduna State.

3.3.0 Experimental Treatments

The experimental treatments consisted of storing eggs, using various methods, during the two distinct seasons in Zaria, Kaduna State in Nigeria. The methods were as follows: Refrigeration, Room temperature, Oiling, Covering with mango leaves and Earthen pot storage.

3.3.1 Refrigeration

Eggs were kept under refrigeration (Plate 3.1) at a temperature of 4^0C. A stand by generator was provided in case of power failure in order to ensure a constant temperature during the experimental period.

Plate 3.1 Eggs preserved in the refrigerator

3.3.2 Room Temperature

Room temperature storage (Plate 3.2) entailed collecting eggs and storing them in paper pulp egg trays on top of a table in a well-ventilated room with an average temperature of 31.79^{0}C during the hot season and 20.75^{0}C during the cold season.

Plate 3.2 Eggs stored at room temperature

3.3.3 Oiling Method

The eggs were dipped in soyabean oil and allowed to drain before placing in egg trays (Plate 3.3) Before the oil was used, it was boiled to prevent introduction of microorganisms then preserved in a well-ventilated room with an average temperature of 31.79^{0}C during the hot season and 20.75^{0}C during the cold season.

Plate 3.3 Eggs preserved with vegetable oil

3.3.4 Covered With Leaves

Fresh mango leaves were used to cover eggs in paper pulp trays placed on table tops (Plate 3.4) in a well-ventilated room at an average temperature of 31.79^0C during the hot season and 20.75^0C during the cold season. The leaves were changed every 3 days.

Plate 3.4 Eggs preserved by covering with mango leaves

3.3.5 Storage in Earthen Pot

Eggs were kept in a wide-mouthed earthen pot that was placed in the centre of a plastic basin at room temperature. The bottom of the basin was filled with sand and earth of equal ratio to a height of 15cm while the side was then filled up to half the height of the pot (Plate 3.5a and 3.5b). The inside of the pot was lined with a thin layer of grass to prevent the eggs being soaked in excess moisture. The eggs were placed in the pot as soon as they were collected and the top covered with a thin cotton cloth to facilitate the exchange of air. 4 litres of water was sprinkled on the sand and earth inside the basin surrounding the earthen pot 2 times a day (i.e. morning and evening).

Plate 3.5a: Earthen pot storage (Outside View)

Plate 3.5b: Eggs stored in earthen pot (Inside View)

3.4.0 Experiment 1: Effect of storage methods and duration of storage on egg Quality indices during the cold season (Dec-Jan)

A total of 967 eggs were used for this experiment. On day 1, Seven (7) eggs were selected at random for determination of internal and external egg quality parameters. These served as the control values for newly laid eggs during the cold season. The remaining 960 eggs were divided into 5 groups of 192 eggs each, which were randomly allocated to one of the following storage methods: refrigeration, room temperature, oiling, covering with leaves, and earthen pot storage. Of the 192 eggs in each of the storage methods, 7 eggs were picked at random at 3 day intervals for determination of egg quality traits. The experiment lasted for 36 days.

Each Egg samples was broken out onto a flat white tray and the following parameters measured:

Yolk width: measured as the widest horizontal circumference with a vernier caliper.

Yolk height: measured at the highest point of the yolk witdth a vernier caliper

Albumen height: this was measured as the height of the chalazae at a point midway between inner and outer circumference of the white with a vernier caliper

Yolk index = [yolk height (cm)/ yolk width (cm)]

Haugh unit: was determined using the formula below:

$$HU = 100 \log (H + 7.5 - 1.7W^{0.37})$$

Where

HU = Haugh unit

H = height of albumen

W = egg weight (grams)

Ease of peeling: The ease of peeling is a measure of the ease with which the egg shell can be peeled. Ease of peeling was determined during the experimental period. At 3 days intervals, 7 eggs were picked from each storage method and cooked by first boiling the water at 100^0c then the eggs are placed in the boiling water for 10 minutes. The boiled eggs were allowed to cool for 10 minutes and then peeled. The ease of peeling was scored on a scale of 1-3. 1= Very Difficult to peel; 2= Difficult to peel and 3= easy to peel.

3.4.1 Microbial Analysis

Two (2) eggs were picked at random from each of the storage methods at 6, 12, 18, 24, 30 and 36 days intervals throughout the 36 days period of the experiment for determination of microbial load in the Microbiology Departmental Laboratory of Ahmadu Bello University, Zaria.

3.4.1.1 Preparation of Media

Twenty eight grams of Nutrient Agar (NA) powder was dissolved in one litre of distilled water, the mixture was then heated to dissolve the agar, then sterilized by autoclaving at 121^{0}C for 15 minutes.

3.4.1.2 Preparation of serial dilutions

Serial dilutions of samples were prepared by arranging three (3) tubes containing 9ml of sterile water each and labelled 10^{-1}, 10^{-2} and 10^{-3} using a sterile blow-out pipette, 1 ml of the sample was transferred into the first tube thus making a 10^{-1} dilution, 1 ml was withdrawn after stirring for 3-5 times to ensure thorough mixing into the second tube to make 10^{-2} dilution. This process was repeated to obtain 10^{-3} dilution.

3.4.1.3 Total aerobic plate count

Sterile blow-out pipettes were used to transfer 0.1 ml of the diluted egg samples (10^{-2} and 10^{-3}) into duplicate plates of appropriately labelled nutrient agar plate. The homogenate was then spread using sterile bent glass rod sterilized using alcohol and flamed. The plates were incubated at a temperature of 37^{0}C for 24 hours. The number of bacterial colonies isolated was counted and the colony forming unit per millilitre (cfu/ml) was calculated as follows:

$$\text{Cfu/ml} = \frac{\text{average colonies in duplicates x dilution factor}}{\text{Volume of inoculumn}}$$

3.4.2 Egg Weight Loss

A total of five (5) eggs were used for this study. The initial weight of these eggs was measured and recorded using a sensitive electronic. An egg was allocated to each of the storage methods and subsequently weighed at three (3) days interval for a period of 36 days to determine the egg weight loss. The egg weight loss was calculated as follows:

Total weight loss (g) = Initial weight – Final weight

3.5 Experiment 2: Effect of storage methods and duration of storage on egg quality indices during the hot season (March-April)

The same procedure outlined in experiment one (1) was repeated during the hot season. The same parameters were taken and similar analysis done.

3.6 Statistical Analysis

Data collected from the experiments were subjected to analysis of variance (ANOVA) using General Linear Model Procedure of SAS. Means with significant differences were separated using Duncan Multiple Range Test.

Statistical model used

$$Y_{ijklm} = \mu+M_i+S_j+T_k+(MT) +e_{ijklm}$$

Where:

Y_{ijkl} = observable traits

μ = population mean

M_i = ith effect of storage method

S_j = jth effect of season

T_k = kth effect of storage time

$(MT)_l$ = lth effect of interaction between storage methods and duration of storage

E_{ijkl} = residual error

CHAPTER FOUR

4.0 Results

4.1 Effect of storage methods on egg weight after storage for 36 days during cold and hot seasons

Table 4.1 shows the effect of storage methods on egg weight after storage for 36 days during the cold and hot seasons. There were significant differences ($P<0.05$) in the weight loss across the different storage methods for both the hot and cold season. The least weight loss was observed in refrigerated eggs followed by oiled eggs and then eggs preserved in earthen pot. Oiled and earthen pot storage were statistically similar ($P>0.05$) in weight for both seasons. The most Rapid loss of weight wererecorded for egg stored under room temperature and those covered with leaves.

4.2 Effect of seasons on egg quality indices.

Table 4.2 shows the effect of seasons on egg quality indices. For all parameters measured: yolk height, yolk width, yolk index, albumen height, and Haugh unit there were significant differences ($P<0.05$) between the cold and hot seasons except for pH which did not show any significant difference between the seasons. From the results obtained, egg quality was better maintained over time during the cold season.

Table 4.1 Effect of storage methods on egg weight loss after storage for 36 days during the cold and hot seasons

Storage methods	Weight loss (g) Cold	Weight loss (g) Hot
Refrigerated	0.43^{d}	0.48^{d}
Room Temperature	5.21^{a}	6.23^{a}
Oiled	1.66^{c}	1.75^{c}
Covering with leaves	4.01^{b}	4.55^{b}
Earthen pot	2.07^{c}	2.07^{c}
SEM	0.21	0.24

^{abc}Means within the same columns with similar superscripts are not significantly different (P>0.05)
SEM= Standard Error of the Mean.

Table 4.2: Effects of season on egg quality indices

	Cold Season	Hot Season	SEM
Yolk Height (cm)	1.38^{a}	0.97^{b}	0.02
Yolk Width (cm)	4.73^{a}	3.88^{b}	0.04
Yolk Index	0.30^{a}	0.24^{b}	0.01
Albumen Height(mm)	4.38^{a}	3.39^{b}	0.06
pH	6.84	6.83	0.01
HaughUnit(%)	62.34^{a}	49.83^{b}	0.74

^{ab}Means with the same superscripts along same rows show no significant differences (P>0.05)
SEM= Standard Error of the Mean.

4.3. Effect of cold and hot seasons on egg quality indices under different storage methods.

Table 4.3 and 4.4 shows the effect of cold and hot seasons on egg quality indices under different storage methods. For all the parameters measured, there were significant difference ($P<0.05$) observed across all the storage methods for both the cold and hot seasons; though the different storage methods during the cold season had higher values for Haugh unit, albumen height, yolk height and yolk index compared to hot season.

4.4. Effect of storage methods on Haugh unit (HU), Albumen height (AH), Yolk height (YH) and yolk index (YI) during the hot and cold seasons.

Tables 4.5, 4.6, 4.7 and 4.8 show the effect of storage methods on Haugh unit, Albumen height, Yolk height and Yolk index. Results obtained showed that there were significant differences ($P<0.05$) in Haugh unit, Albumen-height, yolk height and yolk Index as the duration of storage increased for all the storage methods. Rapid decrease in HU, AH, YH and YI were observed in eggs stored at room temperature and those covered with leaves for both seasons. Refrigeration and oiling methods of storage gave the best result in terms of HU, AH, YH and YI as the storage time increased for both seasons followed by earthen pot storage.

Table 4.3: Effect of cold season on egg quality indices under different storage methods after storage for 36 days

	Storage Methods						
Parameters	Refrigeration	Room Temperature	Oiling	Covering withleaves	Earthen potstorage	Fresh eggs	**SEM**
Haugh unit	70.95^b	55.92^f	66.29^c	58.08^e	59.47^d	74.21^a	0.69
Albumem height	5.06^b	3.90^e	4.86^c	3.92^e	4.09^d	5.27^a	0.06
Yolk height	1.64^a	1.17^d	1.57^b	1.19^d	1.32^c	1.65^a	0.02
Yolk index	0.37^b	0.24^e	0.34^c	$0.25d^e$	0.27^d	0.53^a	0.01
Yolk width	4.43^e	5.03^a	4.58^d	4.90^b	4.84^c	3.13^f	0.07
Yolk pH	6.60^e	7.12^a	6.68^d	7.03^b	6.82^c	6.53^f	0.02

^{abcdef} Means with the same superscripts along same row for each of the seasons show no significant differences (P>0.05); SEM=Standard Error of the Mean.

Table 4.4: Effect of hot season on egg quality indices under different storage methods after storage for 36 days

	Storage Methods						
Parameters	Refrigeration	Room Temperature	Oiling	Covering withleaves	Earthen potstorage	Fresh eggs	**SEM**
Haugh unit	69.17^{b}	30.48^{e}	62.64^{c}	32.03^{e}	52.94^{d}	72.92^{a}	1.25
Albumem height	4.86^{a}	1.20^{b}	4.27^{a}	2.16^{b}	3.49^{ab}	5.15^{a}	0.88
Yolk height	1.35^{a}	0.64^{e}	1.14^{b}	0.71^{d}	0.97^{c}	1.37^{a}	0.02
Yolk index	0.37^{b}	0.14^{e}	0.29^{c}	0.16^{e}	0.23^{d}	0.44^{a}	0.01
Yolk width	3.62^{e}	4.47^{a}	3.63^{d}	3.99^{b}	3.75^{c}	3.10^{e}	0.07
Yolk pH	6.55^{e}	7.12^{a}	6.83^{c}	7.03^{b}	6.83^{c}	6.31^{f}	0.02

^{abcdef} Means with the same superscripts along same row for each of the seasons show no significant differences (P>0.05); SEM=Standard Error of the Mean.

Table 4.5: Effect of storage methods on haugh unit during the hot and cold seasons

	Storage methods											
	Refrigeration		**Room temperature**		**Oiling**		**Covering with leaves**		**Earthen pot**		**SEM**	
Days	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold
1	72.92	74.21	72.92	74.21	72.92	74.21	72.92	74.21	72.92	74.21	0.00	0.00
3	72.92^{a}	74.38^{a}	70.20^{b}	71.63^{a}	69.91^{b}	74.21^{a}	71.07^{b}	69.77^{c}	72.38^{a}	74.21^{a}	0.59	0.92
6	72.75^{a}	74.21^{a}	68.32^{b}	71.23^{b}	69.80^{b}	72.27^{b}	68.61^{b}	69.37^{c}	71.56^{a}	72.91^{ab}	0.85	0.82
9	71.95^{a}	73.99^{a}	60.84^{c}	70.41^{bc}	68.63^{ab}	72.25^{ab}	66.37^{b}	68.71^{c}	70.47^{a}	71.68^{b}	1.94	0.89
12	71.21^{a}	72.23^{a}	55.47^{b}	67.17^{c}	68.05^{a}	69.66^{b}	56.72^{b}	68.70^{bc}	69.23^{a}	70.33^{b}	3.33	0.84
15	69.35^{a}	72.94^{a}	34.32^{b}	62.50^{c}	67.73^{a}	69.20^{b}	32.22^{b}	65.63^{c}	68.43^{a}	69.69^{ab}	8.64	1.80
18	69.08^{a}	72.02^{a}	31.47^{b}	61.52^{c}	67.17^{a}	67.26^{b}	19.79^{b}	63.14^{c}	68.25^{a}	67.55^{b}	10.59	1.84
21	68.65^{a}	71.69^{a}	23.80^{b}	57.35^{c}	61.58^{a}	66.73^{ab}	17.64^{b}	56.39^{c}	61.50^{a}	64.97^{b}	10.70	2.90
24	67.97^{a}	70.84^{a}	20.10^{b}	56.53^{c}	58.84^{a}	66.65^{ab}	15.44^{b}	54.42^{c}	57.24^{a}	62.04^{b}	10.86	3.06
27	67.59^{a}	68.99^{a}	19.82^{c}	50.19^{b}	57.47^{ab}	61.60^{ab}	11.48^{c}	52.94^{b}	39.95^{b}	40.16^{c}	10.69	4.93
30	67.29^{a}	68.68^{a}	0.00^{c}	49.48^{b}	56.09^{a}	59.74^{ab}	5.62^{c}	44.80^{bc}	21.89^{b}	38.61^{c}	13.47	5.36
33	62.03^{a}	68.36^{a}	0.00^{c}	47.86^{b}	54.28^{a}	58.06^{ab}	0.80^{c}	34.36^{bc}	21.41^{b}	33.34^{c}	13.07	6.77
36	60.71^{a}	61.05^{a}	0.00^{c}	47.83^{b}	52.11^{a}	57.81^{a}	0.00^{c}	22.75^{b}	12.93^{b}	31.50^{b}	13.05	7.43

^{abc} Means with the same superscripts along same row for each of the seasons show no significant differences (P>0.05); SEM=Standard Error of the Mean.

Table 4.6: Effect of storage methods on albumen height during the hot and cold seasons

	Storage methods											
	Regrigeration		**Room temperature**		**Oiling**		**Covering with leaves**		**Earthen pot**		**SEM**	
Days	Hot	cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold
1	5.15	5.63	5.15	5.63	5.15	5.63	5.15	5.63	5.15	5.63	0.00	0.00
3	5.15^{a}	5.50^{a}	4.69^{b}	5.27^{bc}	5.10^{a}	5.59^{a}	5.15^{a}	5.13^{c}	5.07^{a}	5.33^{b}	0.87	0.08
6	5.14^{a}	5.34^{b}	4.67^{c}	5.26^{b}	4.93^{b}	5.50^{a}	4.64^{c}	5.09^{c}	4.83^{bc}	5.27^{b}	0.09	0.07
9	5.06^{a}	5.29^{ab}	3.66^{c}	5.20^{b}	4.87^{ab}	5.40^{a}	4.54^{b}	4.96^{c}	4.83^{ab}	5.24^{b}	0.25	0.07
12	5.06^{a}	5.29^{a}	3.41^{b}	4.79^{b}	4.84^{a}	5.27^{a}	3.51^{b}	4.79^{b}	4.74^{a}	5.11^{a}	0.35	0.11
15	4.87^{a}	5.27^{a}	2.11^{b}	4.49^{b}	4.83^{a}	5.17^{a}	2.19^{b}	4.71^{b}	4.57^{a}	5.09^{a}	0.67	0.15
18	4.87^{a}	5.14^{a}	1.63^{b}	4.31^{b}	4.67^{a}	4.96^{a}	1.46^{b}	4.30^{b}	4.51^{a}	4.60^{b}	0.77	0.17
21	4.79^{a}	5.09^{a}	1.29^{b}	3.34^{b}	4.26^{a}	4.94^{a}	1.40^{b}	3.97^{b}	4.03^{a}	4.56^{ab}	0.75	0.32
24	4.71^{a}	4.99^{a}	1.27^{b}	3.34^{c}	3.83^{a}	4.80^{ab}	4.03^{b}	3.70^{bc}	3.43^{a}	4.24^{b}	0.69	0.31
27	4.67^{a}	4.91^{a}	1.26^{b}	2.94^{b}	3.73^{a}	4.41^{a}	1.20^{b}	2.61^{b}	2.23^{b}	2.66^{b}	0.69	0.48
30	4.57^{a}	4.89^{a}	0.00^{b}	2.71^{b}	3.61^{a}	4.06^{a}	0.41^{b}	3.59^{b}	1.39^{b}	2.36^{b}	0.90	0.46
33	4.13^{a}	4.79^{a}	0.00^{b}	2.51^{b}	3.37^{a}	3.91^{a}	0.00^{b}	2.14^{b}	0.00^{b}	2.13^{b}	0.85	0.53
36	4.04^{a}	3.84^{a}	0.00^{b}	2.43^{b}	3.30^{a}	3.91^{a}	1.36^{b}	3.91^{b}	0.93^{b}	2.09^{b}	0.85	0.41

^{abc} Means with the same superscripts along same row for each of the seasons show no significant differences (P>0.05); SEM=Standard Error of the Mean.

Table 4.7: Effect of storage methods on yolk height during the hot and cold seasons

	Storage methods											
	Refrigeration		Room temperature		Oiling		Covering with leaves		Earthen pot		SEM	
Days	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold
1	1.46	1.79	1.46	1.79	1.46	1.79	1.46	1.79	1.46	1.79	0.00	0.00
3	1.44^{a}	1.76^{a}	1.35^{b}	1.76^{a}	1.33^{b}	1.75^{a}	1.22^{c}	1.78^{a}	1.33^{b}	1.65^{b}	0.04	0.02
6	1.42^{a}	1.76^{a}	1.29^{b}	1.68^{a}	1.20^{c}	1.72^{ab}	1.18^{c}	1.69^{b}	1.29^{b}	1.56^{c}	0.04	0.03
9	1.41^{a}	1.72^{a}	1.28^{b}	1.65^{c}	1.15^{c}	1.69^{ab}	1.17^{c}	1.65^{b}	1.26^{c}	1.52^{c}	0.05	0.03
12	1.40^{a}	1.69^{a}	1.11^{c}	1.40^{b}	1.13^{c}	1.68^{a}	1.13^{c}	1.42^{b}	1.24^{b}	1.50^{b}	0.05	0.06
15	1.39^{a}	1.67^{a}	0.86^{c}	1.26^{c}	1.13^{b}	1.65^{a}	1.07^{b}	1.26^{c}	1.15^{b}	1.37^{b}	0.08	0.09
18	1.38^{a}	1.67^{a}	0.53^{c}	1.24^{b}	1.12^{ab}	1.62^{a}	0.94^{b}	1.24^{b}	1.01^{b}	1.30^{b}	0.14	0.10
21	1.38^{a}	1.65^{a}	0.51^{c}	1.14^{b}	1.12^{ab}	1.58^{a}	0.88^{b}	1.04^{b}	1.00^{b}	1.27^{b}	0.14	0.12
24	1.36^{a}	1.61^{a}	0.35^{b}	0.88^{c}	1.11^{a}	1.57^{a}	0.47^{b}	0.92^{c}	1.00^{a}	1.24^{b}	0.19	0.15
27	1.35^{a}	1.55^{a}	0.33^{b}	0.86^{b}	1.10^{a}	1.56^{a}	0.36^{b}	0.91^{b}	0.99^{a}	1.16^{b}	0.20	0.15
30	1.30^{a}	1.51^{a}	0.00^{b}	0.77^{c}	1.06^{a}	1.31^{ab}	0.09^{b}	0.83^{c}	0.87^{a}	1.15^{b}	0.26	0.14
33	1.29^{a}	1.49^{a}	0.00^{b}	0.69^{c}	1.00^{a}	1.29^{ab}	0.00^{b}	0.82^{c}	0.35^{b}	1.08^{b}	0.26	0.15
36	1.25^{a}	1.47^{a}	0.00^{b}	0.51^{c}	0.88^{a}	1.19^{ab}	0.00^{b}	0.62^{c}	0.18^{b}	1.01^{b}	0.26	0.18

^{abc} Means with the same superscripts along same row for each of the seasons show no significant differences (P>0.05); SEM=Standard Error of the Mean.

Table 4.8: Effect of storage methods on yolk index during the hot and cold seasons

	Storage methods											
	Refrigeration		Room temperature		Oiling		Covering with leaves		Earthen pot		SEM	
Days	Hot	cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold
1	0.47	0.57	0.47	0.57	0.47	0.57	0.47	0.57	0.47	0.57	0.00	0.00
3	0.40^{a}	0.43^{a}	0.35^{b}	0.38^{bc}	0.35^{b}	0.40^{b}	0.37^{ab}	0.39^{b}	0.37^{ab}	0.36^{c}	0.01	0.01
6	0.39^{a}	0.42^{a}	0.30^{b}	0.36^{bc}	0.31^{b}	0.38^{b}	0.36^{a}	0.36^{bc}	0.35^{ab}	0.34^{c}	0.02	0.01
9	0.39^{a}	0.40^{a}	0.28^{c}	0.35^{bc}	0.29^{c}	0.37^{b}	0.35^{a}	0.35^{bc}	0.31^{ab}	0.33^{c}	0.02	0.01
12	0.38^{a}	0.39^{a}	0.23^{c}	0.29^{b}	0.29^{b}	0.37^{a}	0.31^{b}	0.30^{b}	0.28^{b}	0.31^{b}	0.02	0.02
15	0.37^{a}	0.38^{a}	0.18^{c}	0.26^{b}	0.28^{b}	0.36^{a}	0.23^{bc}	0.27^{b}	0.26^{b}	0.28^{b}	0.03	0.02
18	0.37^{a}	0.38^{a}	0.11^{c}	0.25^{b}	0.28^{b}	0.35^{a}	0.20^{b}	0.26^{b}	0.23^{b}	0.27^{b}	0.04	0.03
21	0.37^{a}	0.37^{a}	0.10^{c}	0.22^{b}	0.28^{ab}	0.34^{a}	0.19^{bc}	0.21^{b}	0.22^{b}	0.26^{b}	0.05	0.03
24	0.36^{a}	0.36^{a}	0.07^{c}	0.17^{b}	0.27^{ab}	0.34^{a}	0.10^{c}	0.19^{b}	0.22^{b}	0.25^{b}	0.05	0.04
27	0.35^{a}	0.34^{a}	0.06^{c}	0.16^{b}	0.27^{ab}	0.34^{a}	0.07^{c}	0.18^{b}	0.22^{b}	0.24^{b}	0.06	0.04
30	0.34^{a}	0.33^{a}	0.00^{c}	0.15^{c}	0.26^{ab}	0.28^{ab}	0.02^{c}	0.16^{c}	0.18^{b}	0.23^{b}	0.07	0.03
33	0.33^{a}	0.32^{a}	0.00^{b}	0.13^{c}	0.24^{a}	0.27^{ab}	0.00^{b}	0.16^{bc}	0.07^{b}	0.22^{b}	0.07	0.03
36	0.32^{a}	0.31^{a}	0.00^{c}	0.09^{c}	0.17^{b}	0.25^{ab}	0.00^{c}	0.12^{bc}	0.03^{c}	0.20^{b}	0.06	0.04

[abc] Means with the same superscripts along same row for each of the seasons show no significant differences (P>0.05); SEM=Standard Error of the Mean.

4.5 Effect of storage methods on yolk width during the cold and hot seasons

Table 4.9 shows the effect of storage methods on yolk width during the cold and hot seasons. As the duration of storage increased so also the yolk width increased for all the storage methods;refrigeration storage and oiling storage had the least yolk width for both seasons and thus gave the best result followed by earthen pot storage. Room temperature storage and covering with leaves storage increased rapidly in yolk width for both the cold and hot seasons.

4.6 Effect of storage methods on Yolk pH during the cold and hot seasons

Table 4.10 shows the effect of storage methods on yolk pH during the cold and hot seasons. There were significant increases ($P<0.05$) in yolk pH for all the storage methods for both hot and cold seasons. Rapid increase was observed in egg stored at Room temperature and those covered with leaves. Refrigeration storage and oiling storage had the least yolk pH of below 7 at day 36 of storage followed by earthen pot storage for both seasons.

4.7 Effect of storage methods on ease of peeling during the cold and hot Seasons

Table 4.11 shows the effect of storage methods on ease of peeling during the cold and hot seasons. Result obtained showed that the ease of peeling increased for all the storage methods. Eggs stored at room temperature and those covered with leaves ranked high followed by earthen pot storage. Refrigeration storage and oiling ranked low.

Table 4.9: Effect of storage methods on yolk width during the hot and cold seasons

	Storage methods											
	Refrigeration		**Room temperature**		**Oiling**		**Covering with leaves**		**Earthen pot**		**SEM**	
Days	Hot	cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold
1	3.10	3.13	3.10	3.13	3.10	3.13	3.10	3.13	3.10	3.13	0.00	0.00
3	3.60^{b}	4.08^{b}	3.87^{a}	4.58^{a}	3.80^{ab}	4.36^{b}	3.26^{c}	4.53^{ab}	3.57^{b}	4.56^{a}	0.12	0.09
6	3.63^{c}	4.23^{b}	4.33^{a}	4.65^{a}	3.93^{b}	4.53^{a}	3.28^{d}	4.66^{a}	3.70^{bc}	4.62^{a}	0.14	0.08
9	3.64^{c}	4.33^{b}	4.64^{a}	4.71^{a}	3.94^{b}	4.54^{a}	3.31^{c}	4.67^{a}	4.07^{b}	4.66^{a}	0.25	0.07
12	3.67^{b}	4.34^{c}	4.86^{a}	4.85^{a}	3.96^{b}	4.54^{b}	3.64^{b}	4.71^{ab}	4.40^{ab}	4.81^{a}	0.23	0.09
15	3.74^{c}	4.41^{b}	4.86^{a}	4.87^{a}	4.00^{bc}	4.57^{b}	4.60^{ab}	4.71^{ab}	4.40^{b}	4.83^{a}	0.20	0.08
18	3.75^{c}	4.44^{c}	4.93^{a}	4.93^{a}	4.00^{c}	4.58^{bc}	4.60^{ab}	4.71^{b}	4.43^{b}	4.83^{ab}	0.21	0.09
21	3.75^{c}	4.45^{d}	5.07^{a}	5.08^{a}	4.05^{bc}	4.58^{c}	4.69^{ab}	4.90^{b}	4.51^{b}	4.84^{b}	0.23	0.11
24	3.80^{d}	4.47^{c}	5.31^{a}	5.25^{a}	4.05^{c}	4.63^{c}	4.73^{b}	4.94^{b}	4.55^{bc}	4.88^{bc}	0.26	0.13
27	3.82^{c}	4.51^{c}	5.54^{a}	5.26^{a}	4.06^{bc}	4.64^{bc}	5.08^{ab}	5.19^{ab}	4.56^{b}	4.92^{b}	0.32	0.15
30	3.85^{a}	4.55^{b}	0.00^{b}	5.26^{a}	4.07^{a}	4.72^{b}	5.18^{a}	5.21^{a}	4.86^{a}	4.99^{ab}	0.93	0.14
33	3.86^{a}	4.61^{c}	0.00^{b}	5.41^{a}	4.09^{a}	4.74^{bc}	0.00^{b}	5.23^{ab}	5.31^{a}	5.01^{b}	1.11	0.15
36	3.93^{a}	4.70^{c}	0.00^{b}	5.49^{a}	5.08^{a}	4.78^{c}	0.00^{b}	5.38^{ab}	5.34^{a}	5.16^{b}	1.20	0.16

^{abcd} Means with the same superscripts along same row for each of the seasons show no significant differences (P>0.05); SEM=Standard Error of the Mean.

Table 4.10: Effect of storage methods on yolk pH during the hot and cold seasons

	Storage methods											
	Refrigeration		Room temperature		Oiling		Covering with leaves		Earthen pot		SEM	
Days	Hot	cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold
1	6.31	6.53	6.31	6.53	6.31	6.53	6.31	6.53	6.31	6.53	0.00	0.00
3	6.31[a]	6.42[b]	6.31[a]	6.62[a]	6.51[a]	6.53[ab]	6.62[a]	6.65[a]	6.65[a]	6.29[b]	0.76	0.07
6	6.34[b]	6.49[b]	6.29[b]	6.92[a]	6.53[b]	6.53[b]	6.92[a]	6.92[a]	6.92[a]	6.34[b]	0.13	0.12
9	6.38[c]	6.52[b]	6.75[b]	7.09[a]	6.58[bc]	6.58[b]	7.09[a]	6.95[a]	6.95[ab]	6.53[b]	0.13	0.12
12	6.44[c]	6.53[b]	6.80[b]	7.15[a]	6.58[bc]	6.58[b]	7.15[a]	6.95[a]	6.95[ab]	6.69[b]	0.13	0.12
15	6.50[c]	6.56[c]	6.80[b]	7.16[a]	6.62[bc]	6.62[bc]	7.16[a]	7.02[ab]	7.02[ab]	6.80[b]	0.12	0.11
18	6.54[c]	6.63[b]	6.82[b]	7.17[a]	6.64[bc]	6.64[b]	7.17[a]	7.03[a]	7.03[ab]	6.96[a]	0.12	0.11
21	6.59[c]	6.63[b]	6.89[b]	7.18[a]	6.65[c]	6.65[b]	7.18[a]	7.05[a]	7.05[ab]	6.98[a]	0.11	0.11
24	6.65[c]	6.65[b]	6.98[b]	7.20[a]	6.75[c]	6.75[b]	7.20[a]	7.05[a]	7.05[ab]	7.02[a]	0.10	0.10
27	6.66[b]	6.67[b]	7.01[a]	7.21[a]	6.78[b]	6.78[b]	7.21[a]	7.09[a]	7.09[a]	7.08[a]	0.10	0.10
30	6.70[b]	6.71[b]	7.09[a]	7.22[a]	6.79[b]	6.79[b]	7.22[a]	7.19[a]	7.19[a]	7.13[a]	0.11	0.11
33	6.74[b]	6.84[b]	7.13[a]	7.24[a]	6.83[b]	6.83[b]	7.24[a]	7.20[a]	7.20[a]	7.17[a]	0.10	0.09
36	6.75[b]	6.88[b]	7.19[a]	7.29[a]	6.87[b]	6.87[b]	7.29[a]	7.21[a]	7.21[a]	7.19[a]	0.11	0.09

[abc] Means with the same superscripts along same row for each of the seasons show no significant differences (P>0.05); SEM=Standard Error of the Mean.

Table 4.11: Effect of storage methods on ease of peeling during the hot and cold seasons

	Storage methods											
	Refrigeration		Room temperature		Oiling		Covering with leaves		Earthen pot		SEM	
Days	Hot	cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	C0ld
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00
3	1.00^{b}	1.00^{a}	1.43^{a}	1.14^{a}	1.00^{b}	1.00^{a}	1.43^{a}	1.43^{a}	1.14^{b}	1.00^{a}	0.10	0.84
6	1.14^{b}	1.00^{b}	1.43^{b}	1.71^{a}	1.00^{b}	1.00^{b}	2.00^{a}	2.00^{a}	1.43^{b}	1.29^{b}	0.17	0.20
9	1.29^{b}	1.00^{b}	2.86^{a}	2.86^{a}	1.00^{b}	1.00^{b}	2.57^{a}	2.29^{a}	1.57^{b}	1.43^{b}	0.36	0.37
12	1.29^{b}	1.00^{b}	3.00^{a}	3.00^{a}	1.43^{b}	1.00^{b}	2.71^{a}	2.43^{ab}	1.86^{b}	1.86^{b}	0.34	0.43
15	1.57^{b}	1.29^{bc}	3.00^{a}	3.00^{a}	1.57^{b}	1.00^{c}	2.71^{ab}	2.71^{ab}	2.14^{b}	2.00^{b}	0.29	0.39
18	1.57^{c}	1.71^{b}	3.00^{a}	3.00^{a}	1.86^{c}	1.29^{b}	2.71^{ab}	2.86^{a}	2.43^{b}	2.43^{a}	0.22	0.31
21	1.71^{c}	2.00^{b}	3.00^{a}	3.00^{a}	1.86^{c}	1.29^{c}	2.86^{ab}	3.00^{a}	2.43^{b}	2.57^{ab}	0.24	0.32
24	1.86^{c}	2.00^{b}	3.00^{a}	3.00^{a}	1.86^{c}	1.71^{b}	3.00^{a}	3.00^{a}	2.71^{a}	2.86^{a}	0.24	0.27
27	1.86^{b}	2.71^{a}	3.00^{a}	3.00^{a}	2.43^{ab}	2.00^{b}	3.00^{a}	3.00^{a}	2.86^{a}	2.86^{a}	0.33	0.19
30	2.57^{d}	2.86^{a}	3.00^{a}	3.00^{a}	2.71^{c}	2.14^{b}	3.00^{a}	3.00^{a}	2.86^{b}	2.86^{a}	0.05	0.15
33	2.86^{a}	3.00^{a}	3.00^{a}	3.00^{a}	2.86^{a}	2.14^{b}	3.00^{a}	3.00^{a}	2.86^{a}	3.00^{a}	0.07	0.08
36	3.00^{a}	3.00^{a}	3.00^{a}	3.00^{a}	3.00^{a}	2.57^{b}	3.00^{a}	3.00^{a}	3.00^{a}	3.00^{a}	0.17	0.17

[abcd] Means with the same superscripts along same row for each of the seasons show no significant differences (P>0.05); SEM=Standard Error of the Mean.

4.8 Effect of days of storage on colony forming unit (cfu)

Table 4.12 shows the effect of storage days on cfu. Results obtained showed that there was a significant ($P<0.05$) increase in the cfu along the different storage days. As the storage days increased the cfu also increased. Eggs preserved for 6 days were statistically similar to those stored for 12 days in terms of cfu. Eggs that are stored for 36 days had the highest cfu of $4.45x10^{-3}$ followed by those stored for 30 days.

4.9 Effect of storage methods on colony forming unit (Cfu/ml) at 36 days of storage during the cold and hot seasons.

Figure 4.1 shows the effect of storage methods on colony forming unit (Cfu/ml) at 36 days of storage during the cold and hot seasons. Results obtained showed that there was an increase in the colony forming unit (CFU) for all the storage methods. Room temperature storage and covering with leaves storage had the highest CFU while the best result/least was observed in oiled eggs and refrigerated eggs followed by earthen pot storage.

Table 4.12: Effect of days of storage on colony forming unit (cfu)

Days	Cfu
6 days	$1.0x10^{-3}$ [a]
12 days	$1.95x10^{-3}$ [a]
18 days	$3.05x10^{-3}$ [b]
24 days	$3.65x10^{-3}$ [bc]
30 days	$3.85x10^{-3}$ [bd]
36 days	$4.45x10^{-3}$ [c]

[abc]Means within the same columns with similar superscripts are not significantly different

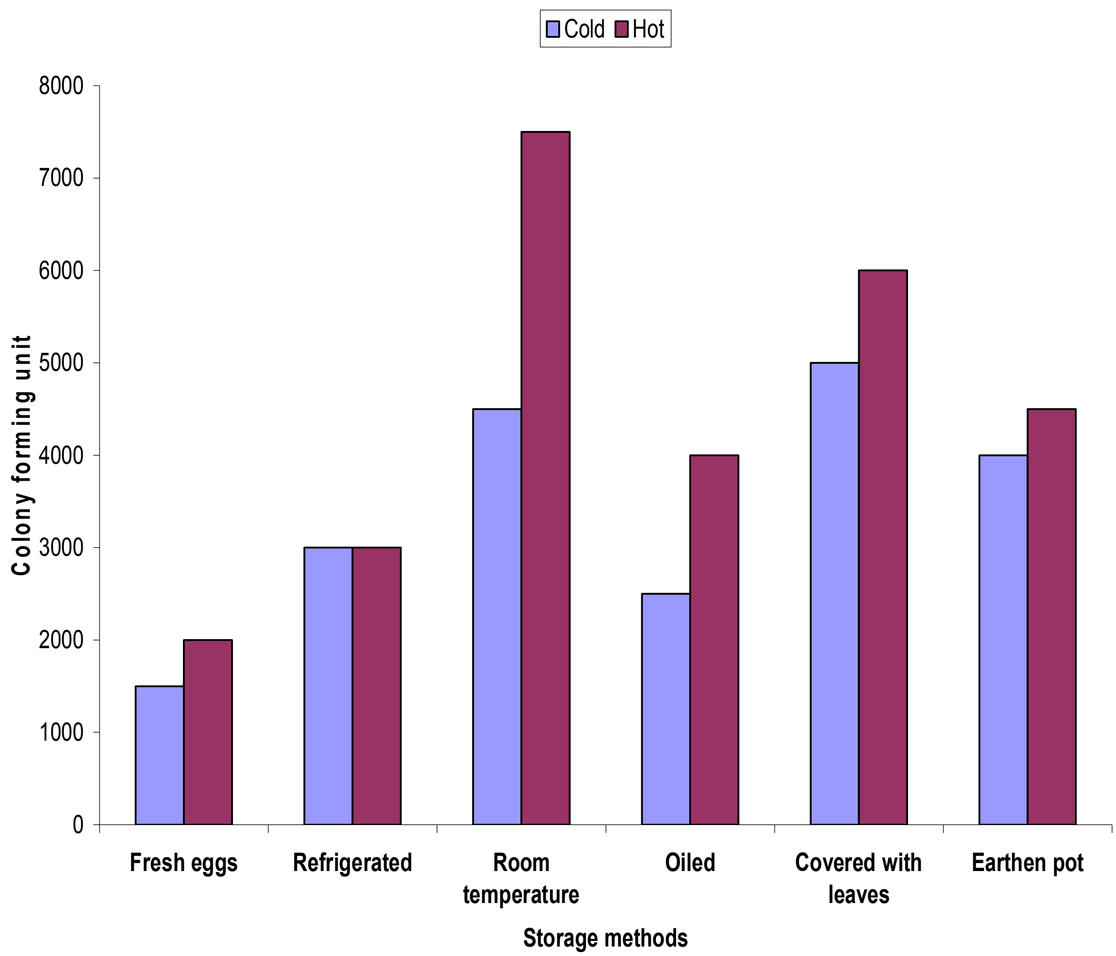

Figure 4.1: Effect of storage methods on colony forming unit (cfu/ml) at 36 days of storage during the cold and hot season

CHAPTER FIVE

5.0 Discussion

5.1 Effects of storage methods on egg weight loss after storage for 36 days during the cold and hot seasons.

The losses observed in weight for all the storage methods agrees with the observation of Okeodu*et al*. (2005) that eggs placed in open bowls and kept under room temperature recorded the greatest weight loss. The change in egg weight during storage is as a result of evaporation of moisture through the shell pores, and this loss of moisture indicates deterioration of egg quality. That the low weight loss was observed in oiled eggs may be attributed to sealing of the pores with oil, reducing evaporation of moisture and gases. Semih and Yasar (2004) reported that in coating, the shell pores are sealed reducing evaporation and carbon-dioxide escape, thus much of the original carbon dioxide is retained and the albumen pHincreases less rapidly. The total weight loss reported in this study is comparable to that reported in the work of Cancer (2005) who observedthat after storage for 4 weeks at room temperature that wax-coated eggs lost an insignificant amount of water.

5.2 Effect of seasons on egg quality indices.

The rapid decrease in egg quality traits observed in this study especially for the hot season is due to the higher temperature. Raji*et al.* (2009) reported that the percentage of firm white is lowered by higher air temperature during the hours immediately after the egg is laid, resulting in an apparent seasonal variation in internal egg quality. They observed that the poorer quality of eggs obtained during summer months is attributed to the higher temperature during this season while the best quality eggs are claimed to be those laid in the spring.

5.3 Effect of cold and hot seasons on egg quality indices under different storage methods

The changes observed in albumen height and Haugh unit during the cold and hot season especially for room temperature storage and eggs covered with leaves is due to carbon dioxide (CO_2) lost through the shell, which makes the contents of the egg to become more alkaline, causing the albumin to become transparent and increasingly watery (Okeudo*et al*., 2003). At higher temperatures, loss of CO_2 is faster and the albumin quality deteriorates faster. Decreasing temperatures in the hotter months during storage will help to reduce deterioration of the albumin. Eggs stored at ambient temperatures and humidity lower than 70% will lose 10-15 HU in a few days from point of lay. By 35 days, these eggs will lose up to 30 HU (Natalie, 2009). Storage of eggs at temperatures of 7-13°C and a humidity of 50-60% will reduce the rate of degeneration of thick albumen proteins and, consequently, egg albumin quality will be maintained for longer (Jones, 2006). Oiling of eggs can also help to reduce CO_2 losses and thus help maintain internal egg quality (Okoli and Udedibie, 2000, 2001; Okeudo*et al*., 2003) but is not a substitute for cool storage.

5.4 Effect of Storage methods on Haugh unit, Albumen height, yolk height, and yolk index.

Haugh unit decreased at significantly ($P<0.05$) different rates among the storage methods. The decrease in HU was most rapid in eggs stored at room temperature followed by those covered with leaves, while eggs that were oiled and those stored in the refrigerator had much slower decreases in Haugh unit for both seasons. This result agrees with the results of Kahraman-Dogan*et al.* (1994) which indicated that HU decreases during storage. The higher values obtained for refrigeration, oiling and earthen pot storage methods is due to the low temperature and relative humidity as reported by Keener *et al.* (2006). Low temperature (using a refrigerator or clay pot) is the most common method of preserving eggs while others include oiling, chemical storage, and pasteurization (Frazier and Westhoof, 1995). Local clay pots buried in the ground around a cool area have been reported to preserve eggs likewise oiling method. Oiling shell eggs is currently an accepted practice for maintaining interior egg quality during storage (Wong *et al.*, 1996). Oiling slowed down the decline in Haugh unit and pH in eggs stored at 28^0C and 12^0C (Sabrani and Payne, 1978). Oil coating checks the loss of moisture and carbon dioxide during storage and penetration of micro organisms. Singh *et al.* (1993) reported that the oil used for sealing must be odourless and colourless.

The rapid decrease in HU in eggs stored at room temperature (RT) and those covered with leaves (CWL) especially during the hot season was due to effect of high ambient temperature. Raji*et al.* (2009) reported that the percentage of firm white is lowered by higher air temperature during the hours immediately after the egg is laid, resulting in an apparent seasonal variation in internal egg quality. They observed that the poorer quality of eggs obtained during summer months is attributed to the higher temperature during this season while the best quality eggs are claimed to be those laid in the spring.

There were significant ($P<0.05$) differences in albumen height for the different storage methods. The height of the albumen indicates the freshness of the egg; the thicker the albumen, the better the quality of the egg, with heights of 8-10mm being considered superior (Zeidler, 2002). Decrease in albumen height was rapid for eggs store in room temperature and those covered with leaves during the hot season but a moderate decrease was observed during the cold season. Refrigeration, oiling and earthen pot storage also resulted in decreases in albumen height as the duration of storage increased, but not as rapidly as those stored under room temperature and those covered with leaves. Villa *et al*. (1990) attributed decrease in albumen height to rise in temperature. This indicates that temperature is one of the main factors influencing the eggs quality during storage.

Yolk height and yolk index decreased ($P<0.05$) for all the storage methods for both seasons. If a fresh egg of good quality is broken out of the shell, the yolk stands up. But as the interior quality deteriorates the yolk flattens out more and more. . The decrease in yolk height and yolk index observed in the study could be attributed to degeneration of the vitelline membrane which allows water from the albumen to move into the yolk and gives the yolk a flattened shape as reported by Okoli and Udedibie (2000).

5.5 Effect of storage methods on yolk width during the cold and hot seasons

The increase in yolk width observed in this study could be due to decrease in vitelline membrane strength (VMS). When eggs are stored for long periods especially under room temperature, the VMS breaks making the yolk to spread into the albumin.Li-Chan *et al.* (1995).Kirunda and McKee, (2000) reported that VMS decreases during storage making the yolk more susceptible to breaking.

5.6 Effect of storage methods on yolk pH during the cold and hot seasons

The significant ($P<0.05$) increases in pH in this study could be attributed to the loss of carbon dioxide from the eggs through the pores in the shell as reported by Hill and Hall (1980). During storage of eggs, the pH of the albumen increases and this is related to the deterioration of albumen quality (Keener *et al.,* 2001). Silversides and Villeneuve (1994), Samli*et al.*

(2005), Akyurec and Okur (2009) reported that pH is a useful means for describing changes in albumen quality overtime during storage. Significant increases in yolk pH were observed with increasing storage time (Salmi *et al.,* 2005).

5.7 Effect of storage methods on ease of peeling during the cold and hot seasons

The ease of peeling was ranked 1-3 (1=difficult to peel, 2=does not peel easily, 3=peels easily). As the duration of storage increased, the peeling becomes easier. According to Bradley and King (2004), "fresh" eggs are more difficult to peel as properly handled eggs that are a few days old contain more carbon dioxide (CO_2) than old eggs and consequently their albumen have a lower pH value. The difficulty encountered in removing the shell of a fresh hard-cooked egg is associated with the low pH of the albumen. As stored eggs lose CO_2, the albumen pH rises; when these eggs are hard-cooked, they are easier to peel (Bradley and King, 2004). In this study, refrigeration, oiling and earthen pot storage methods had a slight increase in peel index compared to room temperature and covering with leaves storage especially during the cold season. These results indicates that refrigeration, oiling and earthen pot storage methods were able to keep the quality of the eggs for a longer period compared to room temperature and covering with leaves storage which lose CO_2 rapidly and therefore peels easily after few days especially during the hot season.

5.8 Effect of days of storage on colony forming unit (cfu)

The increase in Cfu over time observed in this study, especially for eggs stored for 36 days could be due to rapid deterioration in internal egg quality which leads to decrease in shell membrane and vitelline membrane strength (VMS), resulting in easy access to the interior of the eggs by microbes. Previous research has noted that VMS is an important barrier to prevent bacteria transfer betweenthe albumen and yolk (Gast*et al.*, 2005).

5.9 Effect of storage methods on colony forming unit (cfu) at 36 days of storage during the cold and hot seasons

The increase in CFU over time observed in this study, especially for storage at room temperature and covering with leaves could be due to rapid deterioration in internal egg quality which leads to decrease in shell membrane and vitelline membrane strength (VMS), resulting in easy access to the interior of the eggs by microbes. Previous research has noted that VMS is an important barrier to prevent bacteria transfer betweenthe albumen and yolk (Gast*et al.*, 2005). If VMS can be maintainedlonger, then the risk of microorganism penetration into the yolkmay be reduced. The VMS decreases during storage making the yolk more susceptible to breaking (Li-Chan *et al.,* 1995; Kirunda and McKee, 2000). Refrigerator, oiling and earthen pot storage resulted in lower increases in CFU; this is due to the low temperature in the refrigerator and earthen pot storage which slows down deteriorative changes in egg components and also reduces the rate of growth of microorganism; on the other hand oil seals the shell pores and prevent entry of microorganisms. The high level of CFU in this study during the hot season is due to the high temperature and relative humidity which has the opposite effect of low ambient temperature on egg quality and the growth of microorganisms as reported by Park *et al*. (2003)

CHAPTER SIX

6.0 CONCLUSION

Eggs that were oiled and those stored in earthen pot had shelf life of 27 and 24 days respectively during the cold season, since they maintained the USDA specified minimum Haugh unit value of 60, for eggs reaching consumers, for those periods of time. During the hot season, the shelf life was 21 days for both oiled eggs and those stored in earthen pot. Likewise, the colony forming unit was low in oiled eggs and those stored in earthen pot. During the cold season, eggs that were stored at room temperature had a shelf life of 18 days and 9 days during the hot season. Oiling and earthen pot storage methods in this study proved to be the best local methods of storage as they extended the shelf life of eggs.

6.1 RECOMMENDATIONS

It is recommended to poultry farmers to employ the oiling and earthen pot storage as an alternative, to refrigeration, for preserving their eggs

Food outlets that serve boiled eggs should store eggs on the date of purchase so that older ones are used for boiling and fresh ones for frying.

Further studies should be carried out on the economic analysis and acceptance of oiling and earthen pot storage

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