EFFECTS OF PROCESSING TEMPERATURE AND HOLDING TIME ON NUTRITIONAL AND FUNCTIONAL PROPERTIES OF CHICKEN EGGS POWDER

BY

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B. AGRIC. TECH (Hons)

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OCTOBER, 2016

DECLARATION

I hereby declare that this work is the product of my research efforts; undertaken under the supervision of Professor B. F. Muhammad and has not been presented and will not be presented elsewhere for the award of degree or certificate. All sources have been duly acknowledged.

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CERTIFICATION

This is to certify that this research work for this dissertation and the subsequent presentation of this dissertation by MUSA MUHAMMAD UMAR (SPS/13/MAS/00012) were carried out under my supervision

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APPROVAL PAGE

This is to certify that the research work report titled “Effect of Processing Temperature and Holding time on Nutritional and Functional Properties of Chicken Eggs Powder” prepared by Musa Muhammad Umar (SPS/13/MAS/00012) has been examined and approved for the award of the Degree of Master of Science in Animal Science of Bayero University, Kano, Nigeria.

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DEDICATION

This research work is dedicated to my late father Malam Umar Muhammad May his soul continue to rest in peace ‘Amin’.

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ABSTRACT

Effect of processing temperature (40, 50 and 60^{o}C) and holding time (4, 5 and 6hours) on nutritional and functional properties of powdered chicken eggs were determined in a completely randomized design with 3x3 factorial arrangements with 4 replicates. The results showed that temperature and holding time of 40^{o}C:4hours and 40^{o}C:6hours had the highest moisture (8.16%) and crude protein (19.83%) contents while temperature and holding time of 60^{o}C:6hours and 40^{o}C:6hours recorded the highest ash (1.33%) and fat (10.92%) contents, respectively. The temperature and holding time of 40^{o}C:4hours, 50^{o}C:5hours, 60^{o}C:5hours and 40^{o}C:5hours had the highest foaming capacity (20.00%), foam stability (95.65%), water absorption capacity (51.37%) and oil absorption capacity (60.81%) respectively, the highest emulsifying capacity (41.00%) and emulsion stability (22.00%) were recorded at temperature and holding time of 40^{o}C:4hours while highest solubility index (91.00%) was obtained on temperature and holding time of 50^{o}C:4hours. The results of Pearson correlation showed significant negative relationship between foaming capacity and foam stability (r=-0.510), foam stability and emulsifying capacity (r=-0.396), foam stability and solubility index (r=-0.341) as well as between oil absorption capacity and solubility index (r=-0.378). However, significant positive relationship was observed between emulsifying capacity and emulsion stability (r=0.629). The linear regression coefficient indicated that temperature had strong negative effect on moisture (R^2=-1.326), crude protein (R^2=-2.621), fat (R^2=-0.963) emulsifying capacity (R^2=-9.417) and emulsion stability (R^2=-3.250) while holding time had significant negative effect on emulsifying capacity (R^2=-2.167). It could be concluded that the nutrients composition and functional properties of powdered chicken eggs were not adversely affected by processing temperature and holding time of the study. Hence, it could be incorporated as nutritive ingredient in the production of food products.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Nigeria is a country with heavy human population of about 160 million (NPC, 2009) and this population is continuously on the rise. This increase had led to the high demand for the available animal protein source from different species of livestock and poultry in all parts of the country. Among the cheapest and highly affordable animal protein source for this teeming population is an egg from poultry industry. The poultry industry is an important segment of Nigeria's food industry, providing meat and egg to the populace. Egg is one of the most versatile and near perfect food in nature (Kumaravel *et al.,* 2012). It is rich in protein, vitamins and most mineral substances, the white and yolk components are all of high biological value and are readily digested. They are known to supply one of the best protein (Vaclavik and Christian, 2008; Kumaravel *et al.,* 2012).

Egg is a complete protein with excellent quality; one egg will give 6g of protein and egg-white protein has a biological value of 100, the highest biological value of any single protein (FAO, 2005). Eggs have a number of uses apart from domestic consumption in households; they are used in confectionary (Tijani *et al.*,2006), bakery products (Ali and Mudassar,2012), ice cream and cosmetic (Mine and Kovacs-Nolan, 2004). Their functional properties of emulsification, thickening, foaming and moisturizing help contribute desirable characteristics and physical functions in industrial production of many food products in which they are incorporated (Kumaravel *et al.,* 2012). Egg also gives significant color and flavor (from the yolk portion) and enrich nutritional value of cake (DesRochers *et al.,* 2003).

The nutritional status of many Nigerians is characterized by low protein intakes (FAO 2005).The average daily animal protein intake is still far less than the 35 g per adult per day recommended by FAO (2007). Adepoju (2008) and Nmadu *et al*. (2014) reported the average *per capita* protein intake in Nigeria as 51.7 g of which only 6.8 g came from animal sources. However, in developed countries, the average *per capita* protein intake was 90 g with more than 65 g of animal protein.

Eggs are accepted by most cultures and religions; it constitutes an interesting tool in solving the world nutrition problem. Presently, the demand for eggs is rapidly changing due to the changes in consumption habits and to the great development of past food catering (Tijani *et al.*,2006). The importance of eggs in industries other than agro-alimentary is also growing. Its antioxidant, antiviral, antibacterial, emulsifying and coagulating properties are indeed valorized in the pharmaceutical and cosmetic sectors (Mine, 2002; Mine and Kovacs-Nolan, 2004; Moula *et al.,* 2009).

Qualities of eggs comprises a number of aspects related to the shell, albumen and yolk and may be divided into external and internal (Kul and Seker, 2004). According to Keener *et al.* (2005) haugh unit is a measure of albumen quality and therefore freshness of the egg. However, fresh eggs are difficult to transport because of their bulkiness, fragility and high perishability nature (Jay, 2000; Kumaravel *et al.,* 2012).

1.2 PROBLEM STATEMENT

Production of eggs is on the increase in Nigeria and poor storage conditions may result in deterioration in egg quality and consequently, loss and waste in eggs (Raji *et al.,*2009). Jones and Musgrove (2005) reported a decrease in albumen height and weight with storage leading to decrease in egg weight.

Since storage environment influence the quality of eggs, methods like lower temperature and modified atmosphere packaging such as refrigeration have been recommended (Chang and Chen, 2000; Dudusola, 2009). However, in some parts of Nigeria, most of the available eggs are usually stored at room temperature until they are completely sold or consumed because facilities for refrigeration are constantly affected by epileptic power supply (Raji *et al.,*2009*)*

Eggs are perishable foods and highly susceptible to the growth of microorganisms (Northcutt *et al*., 2004; Ali and Mudassar., 2012). Raji *et al. (*2009) recommend that in the hot dry climate, eggs should not be stored at room temperature beyond one week before consumption. Egg producers/marketers encountered problems such as transportation due to bad roads and poor condition of vehicle leading to broken and damage eggs which further lead to reduction in egg value (Mohammed *et al.,* 2013).

1.3 JUSTIFICATION OF THE STUDY

Processing of egg in to egg- powder provides a near complete solution to perishability, loss and waste of eggs due to poor handling/breakages. Several processing and preservation methods like spray drying, tray drying and freeze drying techniques have been adopted with repercussion on qualities of the products (Potter and Hotchkiss, 2006)

Whole egg powder, egg white powder and egg yolk powder was produced using oven drying method at controlled temperature of $44^{o}C$ for 4hrs without adversely affecting Nutritional properties (Kumaravel *et al.,* 2012). Powdered egg was reported as a nutritive ingredient in the production of healthy food products (Ndife *et al.,* 2010). Kumaravel *et al.*(2012) reported that in the original packing, at normal odor free condition of less than $25^{o}C$ at 65% relative humidity, powdered egg could be kept for 18 months.

Egg proteins can withstand severe heat treatments when sugar and salt are present during the process. Depending on the sugar and salt concentrations, whole egg and egg yolk solution can be heated at temperature as high as 80^{o}C for 2 minutes without effect on their emulsifying properties (Campbell *et al.,* 2005). Rene and Suzana (2007) reported insignificant changes in the yolk protein content after spray drying .However, coagulation and/or precipitation of egg white were observed at temperature of 74^{o}C for 20 minutes (Zoubida *et al.,* 2012). High storage stability, good handling and easiness in transportation are shown by spray dried food powders as compared to liquid food materials (Obon *et al.,* 2009).

1.4 OBJECTIVES OF THE STUDY

The broad objective of the study is to determine the effects of processing temperature and holding time on nutritional and functional properties of chicken eggs powder and the specific objectives are:

i. To determine the suitable temperature and holding time for chicken egg powder production in semi-arid zone of Nigeria
ii. To determine the nutritional properties of chicken egg powder produced under different oven drying temperature and holding time.
iii. To determine the functional properties of chicken egg powder produced under different oven drying temperature and holding time.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 ORIGIN AND DOMESTICATION OF CHICKEN

Poultry, particularly chickens are very important and has been recognized as an important genetic resource among the avian species (Olowofeso *et al.,* 2005). Genetic evidence confirms that chickens are derived from multiple maternal origins in Asia (Liu *et al*., 2006). Chickens are the most widely distributed of all livestock species in Nigeria with a population of 166 million birds (FAOSTAT, 2007). Chickens play very significant socio-cultural and economic roles in most African societies. Quantifying the structure of genetic diversity in different African chicken populations is of significance in optimizing conservation and utilization strategies. The description of Nigerian local chickens is based on phenotypic traits (Nwosu *et al*., 1985; Adebambo *et al*., 1999). Such information if complemented with findings obtained using molecular markers could be useful in formulating long term inference and plans for genetic improvement programs. A detail genetic study of chicken populations in Nigeria is therefore imperative so as to integrate the resource into the poultry sector. The genetic variations of the chicken populations in the country need investigation so as to identify populations of particular merit.

Eggs of most species of birds may have similarities in nutritional composition and potential food usage. Chicken egg has been very well studied for its quality as well as for its composition, however such information are not so abundantly documented in other poultry species (Dudusola, 2010). Quality characteristics such as cleanness, freshness and egg weight and shell quality are important for consumer´s acceptability of shell eggs. Other characteristics such as yolk index, albumen index, proportions of egg components and chemical composition are important for egg production industry (Song, 2000).

2.2 EGG PRODUCTION

In recent years, the poultry industry has occupied a leading role among agricultural industries in many parts of the world. South America Africa and Asia show the greatest increase in egg production, 32.5% 35.2% and 46.9% respectively. While North and Central America, Europe 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 in egg production since the level of consumption is still very low (USAD, 2000). 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 considered the most qualitative of the human foods (Vaclavik and Christian, 2008). 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 2006. In the UK, over 26 million eggs are produced (MAFF, 2006).

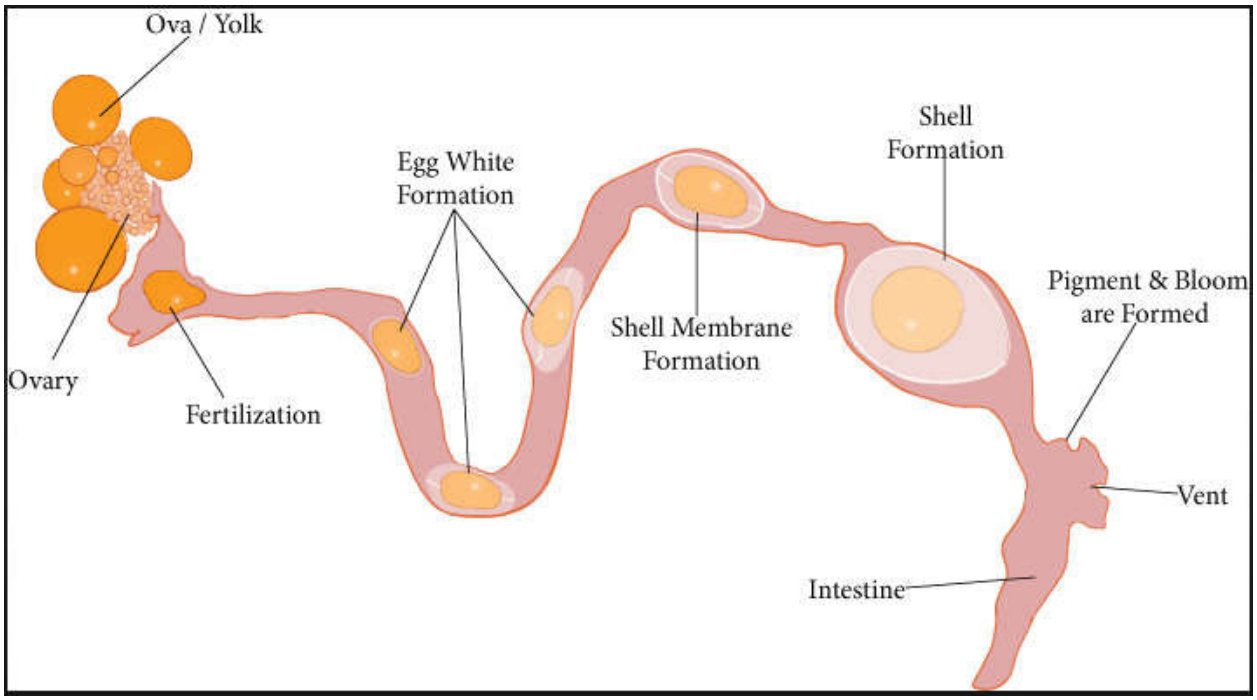

Figure 1**:** Process of egg formation (Mine, 2000)

2.3 STRUCTURE OF 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 chicken's egg contains approximately 64% albumen, 27% yolk, 9% chalazae and 0.75% shell membrane (Rose, 1997).

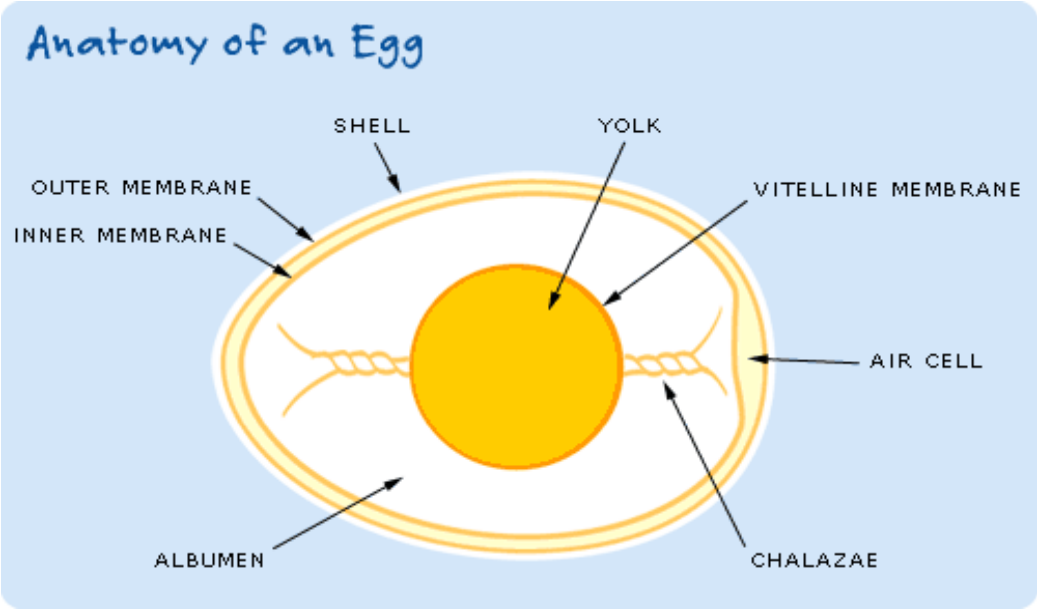

Figure 2: Diagram of a chicken egg (Mine, 2002)

2.3.1 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 a difference among individual hens even when all are of the same breed and variety (Jacob *et al.,* 2000). In general, chicken breeds with white ear lobes lay white eggs, while breeds with red ear lobes lay brown eggs. The local chicken has both white and brown eggers (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 content of diet also plays a vital role in determining the egg texture. High phosphorous and low calcium levels in the diet causes ridging and distortion of the shell (Jacob *et al.,* 2000).

2.3.2 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 microorganisms 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). 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 QUALITY PARAMETERS

2.4.1 Egg Size and egg weight

Body weight appeared to be the main factor influencing early egg size. There is general and direct relationship between body size of birds and the size and weight of eggs laid. Birds with large body size lay large eggs and vice-versa (Singh *et al.*1992*).*

Dietary protein increase and methionine level had little or no effect on egg size and weight for the first 12 weeks of production, linoleic acid levels also fail to show any influence on egg size during the same period (Summer and Leeson, 1990). Egg size and weight are also influenced by age and season of laying (Singh *et al.*1992*).*

2.4.2 Egg shape

There are great variations in shape of avian eggs. Eggs laid by chicken may be similar however not 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, miss shaped, 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).

2.4.3 Egg colour

Egg colour often has economic importance as there are local prejudices in favor 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 factor. Egg shell colour has no effect on internal egg quality involving structural properties, and microbial population of the egg yolk and albumen. The proportions of components for eggs are 32% yolk, 58% albumen and 10% shell (Leeson, 2006).

According to USAD (2000) the egg white consists of four structures;

- The chalaziferous layer or chalazae, immediately surrounding the yolk, accounting for 3% of the white.
- The inner thin layer, which surrounds the chalazae and accounts for 17% of the white.
- The firm or thick layer, which provides an envelope 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.
- 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 freshly laid egg is round and firm. As the egg stay longer, the yolk, absorbs water from the egg white, increasing its size; this stretches and weakens the vitelline membrane making the yolk flatter. 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) reported 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 freshly 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.

Table1**:** Nutritional Composition of Raw Liquid Egg

	Whole egg	Whites (%)	Yolks	Yolks (commercially separated)
Water	73.7	87.6	51.1	55.5
Protein	12.9	10.9	16.0	15.4
Fat	11.6	Trace	30.6	26.9
Carbohydrate	1.1	1.1	1.0	1.0

(Li chan *et al.,* 1995)

Yolks separated under laboratory conditions include only a small proportion of white; commercially separated yolks include considerable white. Egg white is composed of 9.7to10.6% protein by weight. Over 24 different proteins have been identified and isolated from egg white

(Mine *et al.,* 2004). Some of the major proteins include ovalbumin, ovotransferrin, ovomucoid, ovomucin and lysozyme (Mine, 1995). Table. 2 lists important proteins of egg white their percentages and denaturation temperature as reported by Andrew (2010).

2.5 EGG WHITE PROTEINS

Table2: Type of protein in Egg white and denaturation temperatures

Proteins	% Protein in Egg white	Denaturation Temperature (^{o}C)
Ovalbumin	54	84.0
Ovotransferrin	12	61.0
Ovomucoid	11	77.0
Ovomucin	3.5	-
Lysozyme	3.4	75.0

(Andrew, 2010).

2.5.1 Ovalbumin

The most abundant and central protein to egg white's functional properties in food is ovalbumin. Ovalbumin has a molecular weight of 44.5 Kilodalton (kDa) and is monomeric phosphoglycoprotein with a known complete amino acid sequence of 385 residue (Doi and Kitabatake, 1997). It is a storage protein and major source of amino acid for the developing embryo (Mine and Yang, 2008). Ovalbumin is a heterogeneous molecule with variation in its composition, which include the degree of phosphorylation, glycosylation and genetic variance. S-ovalbumin is found naturally in egg white and contribute to ovalbumin heterogeneity. It is an alternative form of ovalbumin with greater heat stability and is known as "stable" ovalbumin. The presence of S-ovalbumin is confirmed by the difference in denaturation temperature at

92.5°C compared to 84.0°C for ovalbumin. Other properties of S-ovalbumin such as molecular weight, sulfhydryl content, crystal formation and electrophoretic separation are indistinguishable from ovalbumin. S-ovalbumin has also been found to have increased surface hydrophobicity (Kilara and Harwalker, 1996). The mechanism for conversion of ovalbumin to S-ovalbumin has not been confirmed but may be a result of deamination or partial reactive loop insertion (Huntington and Stein, 2003). The crystal structure of S-ovalbumin has been determined and shows no difference in secondary structure with ovalbumin

2.5.2 Ovatransferrin

Ovatransferrin is the second most abundant egg white protein accounting for 12% of protein in egg white. It has a molecular weight of 77.7 kDa and is a glycoprotein consisting of 686 amino acid residues (Mine, 1995). Ovatransferrin is a member of iron binding protein group known as transferrins. Its iron-binding activity, $K_D=10^{-29}$M (Kilara and Harwalker1996), is thought to be responsible for the antimicrobial properties of protein. The metal-binding action helps helps to stabilize the protein raising the denaturation temperature from 61°C to around 72°C when iron is bound (Kilara and Harwalker., 1996).

2.5.3 Ovomucoid

Ovomucoid is a glycoprotein with a molecular weight of 28.0 kDa. About 25% of the protein has its carbohydrates attached via Aspertate (Asp) residues. Ovomucoid is a well known trypsin inhibitor. Ovomucoid is very stable due to its multiple disulfide bridges and is physicochemical unchanged under acidic conditions at 100°C for long periods of time (Kilara and Harwalker, 1996). However, with extreme heat, trypsin inhibitory activity and

immunoreactivity with some antibodies is lost due to the reduction and alkylation of disulfide bonds (Nakamura and Doi, 2000).

2.5.4 Ovomucin

Ovomucin is a viscous glycoprotein that composes 1.5-3.5% of protein in eggs white. Its molecular weight ranges between 5.5 to 5.8 x 10^3 kDa (Mine, 1995). Ovomucin is insoluble in water unless in the presence of salt or at > P^H 9 (Nakurama and Doi, 2000). Ovomucin is an inhibitor of virus hemagglutination and is an important determinant for egg quality (Kilara and Harwalker, 1996) as the thinning of egg white is thought to be caused by disassociation of α-ovomucin from soluble ovomucin (Nakurama and Doi, 2000).

2.5.5 Lysozyme

Lysozyme was the first protein to be sequenced and is one of the most studied egg white proteins. It is a small protein consisting of 129 amino acids with a molecular weight of 14.3 kDa (Lesnierowski and Kijowsi, 2007). Lysozymes are group of enzymes with antimicrobial function. The reduction of more than 2 of the disulfide bonds results in a loss of bioactivity (Lesnierowski and Kijowsi, 2007). However, reduction in disulfide linkages significantly improves functional properties including gelation and foaming (Doi and Kitabate, 1997). Along with its role in interaction with other proteins during foaming and gelation, lysozyme may play a role in thinning of egg white during storage through electrostatic interaction with ovomucin (Mine, 1995).

Table 3: Percentage Composition of Egg

Parts	Percentage (%)
Albumen	55.8p
Yolk	31.9
Shell	12.3

(Mine, 1995)

2.6 EGG CONTAMINATION

Poultry manure contains a variety of pathogens, some are host adapted and therefore not a health risk for humans. Others can produce infection in humans. The more common zoonotic pathogens manure in poultry manure includes; *Escherichia coli, Campylobacter, Salmonell*a, *cryptosporidium parvum, and Giardia lambia* (Kinde *et al.,* 1996).

The egg products inspection act of the early 1970s (USDA, 2000) essentially brought an end to egg associated *salmonella* infections, in humans at least for a short time. Intact shelled eggs were considered safe, essentially sterile food product until a study published by St. Louis *et al.* (1988) linked the increasing number of food borne *Salmonella enteridis* outbreaks. The production of *salmonella enteridis* contaminated eggs in an infected flock is sporadic and reported the incidence is low (Kinde *et al.,* 1996). *Salmonella enteridis* remains the principal *Salmonella serovar* for egg contamination, but it is not the sole agent in this problem. *Salmonella heidelberg* (Hennesy *et al*, 2004) have also been implicated in egg borne human *Salmonella* outbreaks and must be considered in overall problem, Phage typing and plasmid profiles of the environmental isolates were identical to those recovered from the hen. This indicates that the environmental *Salmonella enteridis* originated from the birds (Mutalib *et al*., 1992) and demonstrated that although only a proportion of the birds may be infected at any time, the birds

continual excretion of pathogens will progressively increase the pathogen levels in the surrounding environment (Mutallib *et al* 1992). This statement was made based on the findings of Kinde *et al.* (1996).

Mutalib *et al*. (1992) reported that some routine monitoring for *Salmonella* was carried out in breeding flocks, bacteriological techniques based on sample taken from individual birds and pooling samples had shown low sensitivity compared with indirect environmental monitoring. Studies from the European food standard agency (EFSA 2004) in the EU used environmental sampling.

It is not clear the impact of different production systems on farm *Salmonella* infection rates. The environmental testing of layer flocks in the EU showed a higher prevalence of *Salmonella* in flocks housed in conventional cages on the floor. This was observed in studies from multiple countries; Germany (Methner *et al* 2006), Belgium; (Namata *et al*., 2008), United kingdom; (Snow *et al*., 2009). Furthermore, in a retrospective epidemiological study in Denmark (Molbak and Neimann 2002) it was observed that eggs from conventional cages were associated was found with eggs from free range or organic operations. USDA and animal and Plant Health Inspection Service in collaboration with National Animal Health Monitoring System of layers reported that pullets raised in conventional cages have lower incidences of *Salmonella enteritidis* than floor raised pullets (USDA 2000) .

The study of (Mollenhorst and Neimann, 2002) used serology rather than culture methodology to detect egg infection status. One of the factors that can affect the prevalence of bacteria on premise is flock size (snow *et al*., 2009). Possible explanation for this increase in incidence may be the higher densities of birds in these facilities with the increased volume of

contaminated faeces. Bacteria could potentially penetrate through eggshell (Messen *et al.,* 2005). Thus, shell contamination with faecal bacteria may be an important source of contamination.

2.7 NUTRITIONAL VALUE OF EGGS

The egg has long been known for its exceptional nutritional value. It consists of a porous carbonate shell, yolk and albumen commonly known as egg white. The yolk makes up 1/3 of the egg and contains most of the vitamins including A, D, E, K and B-complex vitamins. The yolk also contains essentially all of the lipids, ¾ of the calories, and is good source of antioxidant carotenoids. In contrast, egg white contains over half of the proteins in egg and is a source of the vitamin riboflavin (Mine*,* 2002). Egg whites are low in lipids (0.01%) as reported by Mine*,* (1995) making egg white a healthy source of protein and other nutrients

Eggs are excellent source of high quality protein and one of the best low-price sources. It has been revealed that eggs contribute the highest food protein quality after mother's milk. Eggs have all nine amino acids which are essential to our body and (histidine, leucine, lysine, isoleucine, threonine, tryptophan, methionine, phenylalanine and valine). Because the essential amino acids in egg protein have the same pattern as the pattern of amino acids needed by the human body that's why egg is often utilized as standard of comparison for determining the quality of protein with other foods (AEB, 1999). In addition to this, eggs are very good sources of leucine. The amino acid leucine is essential and that increases the energy using ability of muscle and help muscle recovery after resistance and dynamic exercise; muscle utilize complementary effect between glucose and leucine so men and women doing resistance exercise can have advantage from leucine rich diet. Even though leucine is an important element in regulation of muscles and synthesis of protein and may be the key amino acid optimizing the

skeletal muscle mass by defining increased essential amino acids need (Layman and Rodriguez, 2009).

Eggs contribute little to considerable quantity of all minerals and vitamins which are known to be needed by the human body, excluding vitamin C (AEB, 1999). Eggs are also excellent source of choline, folate and selenium, nutrients which are required for normal development of brain (Herron and Fernandez, 2004). The egg white and the egg yolk contribute essential nutrients to the human body. An average large egg contributes 6.25 g of high-quality protein based on 10-12% of the Daily Reference value for protein, one egg also contributes around 200 milligrams of cholesterol (Ali and Mudassar, 2012); which nearly meet the dietary cholesterol intake limit as established by the American Heart Association at ≤ 300 mg/d (AEB, 1999).

2.7.1 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 average egg provides approximately 647 kilojoules of energy, of which 80% comes from the yolk (USDA, 2000).

2.7.2 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 that is Vitamin A, D, E and K (Rose, 1997).

2.7.3 Minerals

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

2.8 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 include colour of shell, shell porosity, shell strength, albumen conditions, yolk shape and colour, flavour, cleanliness, presence of meat and blood spots (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).

2.8.1 Measures of Egg Quality

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

- External appearance
- Odour and flavour
- Physical characteristics of components of the opened egg

(Rose, 1997).

Mertens,(2009) has reported that 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.

2.9 EGG HANDLING

On farm, eggs should be collected regularly and kept in cool and ventilated stores. Dirty eggs (as a result of litter or collection) should be cleaned with abrasive materials in preference to washing. If it is necessary to wash, the water temperature should be 38 to 43^{o}C and change every few minutes. Washed eggs should not be stored for a very long time because as eggs ages it loses carbon dioxide and moisture through the shell pores and the cuticles covering the shell is washed away which prevents escape, this cause the air cell within the egg to become large. With these losses of carbon dioxide, the egg pH becomes more basic and structural changes takes place in the albumen which leads to the thinning of the albumen (Oluyemi and Roberts, 1992).

2.10 CLEANING OF EGGS

Dirty eggs are covered with bacteria that will cause spoilage if they penetrate the egg shell (Singh *et al.,* 1993). Dirty eggs could be dry cleaned easily with the help of cloth or fine sand paper which may be used to scratch out dirty spots or stains (Semih and Yassar,2004). Wet washing of dirty eggs may 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 could become contaminated with manure or other foreign materials. Egg with manure or adhering material is unattractive in the appearance and may 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).

2.11 PRESERVA OF EGGS

Liquid eggs 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 in which 60-65% moisture content of the egg escapes (Nesheim *et al.,* 1979).

2.11.1 Lowering of Temperature

Chilling using a refrigerator or cooling in clay pots is one of the most common method of preservation of eggs. 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 (Keener *et al.,* 2005).

2.11.2 Shell Coating

Oiling has also been reported (Semih and Yasar, 2004) as an effective method in egg preservation. The coating method of the egg shell 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 (Lee, 2000). Raji *et al.* (2009) suggested that coating the eggs several hours after laying is most effective.

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). 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.

Limewater has also been discovered to be an effective egg preservation method (Keener *et al.,* 2001). Eggs preservation using limewater involves the following steps:

- To prepare limewater for preservation of egg, dissolve 1 pound of salt and 1 quart of finely slake lime in 3 gallons of water, stir solution at frequent interval for a day or to and then allow the liquid to settle.

- Place the eggs in crock or keg with their pointed end turned down, fill the receptacles to within a few inches of the top
- Pour the clear limewater over the eggs so arranged, allowing it to rise an inch or two above the top layer
- Then stand the vessel in a cool place where the temperature will not exceed 50 degree Fahrenheit.
- Eggs so treated could be kept for at least 6 or 8 months.
- The only objection to this method is that, the egg preserved by it sometimes a slight lime taste.

(Warren and Scott, 1990)

2.11.3 Pasteurization of Eggs

Pasteurization of eggs is a process which is intended to destroy harmful microorganisms, specifically *Salmonella enteritidis* that may be present on or in the egg (USDA, 2000). Pasteurization is done by immersing eggs in hot water of a specified temperature for a specified duration. The optimum time and temperature is reported as 62.5^{o}C for 2 minutes (Singh *et al.,* 1992). The keeping quality of thick albumen has been found to improve with this heat treatment of between 60-65 ^{o}C, egg yolk 65-70 ^{o}C and beaten whole egg 68 ^{o}C. The temperature at which an egg coagulates may be changed (raising or lowering). To raise coagulation temperature sugar is added or by lowering the number of eggs being used and to lower the coagulation temperature salt is added or by increasing the number of eggs being used. Coagulation may be lowered by the addition of acid, such as vinegar or lemon juice. But excessive heat could affect the egg products.

2.12 QUALITY CONTROL

The application of the knowledge of the manufacturing, marketing and distribution of a product with the optimum level of quality is referred to as quality control (QC). 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).

2.13 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 may 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. The USDA egg grading specifications are: *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. 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. 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.

2.13.1 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 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:

- cracks due to excess pressure;
- cracks due to thin shells;

- body-checks;
- Pimpled or toe holes, and
- Shell-less eggs

(Juliet *et al.,* 2004)

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).

2.13.2 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)

Egg yolk from a freshly laid egg is round and firm. As the egg stay longer, the yolk absorbs water from the egg white, increasing its size; this stretches and weakens. The vitelline membrane makes the yolk flatter. 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 (CO_2) 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 freshly 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 CO_2 (Jin *et al*., 2011).

2.13.3 Factors Affecting Quality of Eggs

Freshly 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.

Bolukbasi *et al*. (2007) 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 egg looks and smells putrid when broken out of the shell (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 (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).

2.14 METHODS OF EGG QUALITY DETERMINATION

2.14.1 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). It is possible to manipulate the yolk colour of eggs by the addition of natural or synthetic xanthophyll 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 (Okeudo *et al*., 2003).

2.14.2 Yolk Firmness

The yolk of a freshly laid egg is round and firm (Lee, 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.

2.14.3 Yolk Texture

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

2.14.4 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). The factors affecting albumen quality include:

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. The author further noted that under 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.

Storage time of the egg: As the egg stay longer, 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 (Okeudo *et al*., 2003). Storage of eggs at temperatures of 7-13°C and a humidity of 50-60% may reduce the rate of degeneration of thick albumen proteins and, consequently, egg albumen quality will be maintained for longer (Jones, 2006). Oiling of eggs could also help to reduce CO_2 losses and thus help maintain internal egg quality (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 Hens consuming as little as 6 pm. Sell *et al*. (1986) showed that the interior quality, of eggs decreased in two strains of laying hens fed 3 or 6 ppm added vanadium. Henry and Miles (2001) reported that the negative effects of vanadium may be overcome by feeding cottonseed meal**,** ascorbic acid, vitamin E or carotene at a recommended dose.

Diseases: Diseases such as Newcastle disease may also cause a decrease in albumen consistency (Jacob *et al*., 2000).

2.14.5 Albumen Appearance

Normal albumen is transparent, with a slightly yellow green colour. Cyclo-propene fatty acids from cottonseed meal and the certain weed seeds (Sell *et al.,* 1986) may 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 (Sell *et al.,* 1986).

2.14.6 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 could 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).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.

2.15 OVEN DRYING OF EGGS

Drying or dehydration is one of the oldest and one of the popular methods for preservation purpose. Records indicate that vegetable drying was performed as early as 18^{th} century. Development in drying has been gradual and it addresses issues on industrial requirements. Different kind of dryers have been developed to address specific requirements such as solar drying, drum drying, spray drying, spouted bed drying, fluidized bed drying, microwave drying, freeze drying and oven drying (Vega-Mercado *et al.,* 2001). Oven drying provide a dried powdered egg product which does not become rancid or undergo the so-called browning reaction which occur in spray dried egg product (Kumaravel *et al.,* 2012)

2.16 FUNCTIONAL PROPERTIES OF EGG

Functional properties of Food determine the application and use of such Food materials as ingredient for production of various Food products (Wilcox, 2006). Egg's functional properties of emulsification, thickening, foaming and moisturizing help contribute desirable characteristics and physical functions in industrial production of many food products in which they are incorporated (Kumaravel *et al.,* 2012). Emulsification properties of Food materials are necessary for the stability of suspension of one liquid in another. Yolk portion of egg is responsible for the emulsifying properties of egg because it contain fat and lecithin (Ali and Mudassar, 2012). The foaming properties are particularly important in stability of ice cream and in bread production (Wilcox, 2006). The thickening power of egg powder decreases rapidly with aging of the egg powder during formation of sponge cakes (Ali and Mudassar, 2012).

Egg albumen has excellent food foaming properties. Such properties are determined by the ability to rapidly adsorb on the air-liquid interface during whipping or bubbling, and by its ability to form cohesive viscoelastic film by way of intermolecular interaction (Mine, 1995). Since egg white proteins are extensively utilized as ingredient in the food processing, the researches of many scientist is directed towards the improvement of functionality of egg white proteins.

The many uses of egg yolk products in the food industry are basically a result of three functional properties: manufacture and stabilization of emulsion, foaming stability and thermal gelation. The functional properties as well as the quality of the final products are highly influenced by the rhelogical properties of yolk-containing phase (Gallegos and Franco, 1999. Therefore, knowledge of the rhelogical properties of yolk products is important for its

commercial applications. The rhelogical behavior of egg yolk showed itself to be pseudoplastic and dependent on temperature (Telis-Romero *et al*., 2006).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STUDY AREA

The experiment was conducted at the laboratory of the Department of Animal Science, Bayero University, Kano. Kano which is located in semi-arid zone of Nigeria (Latitude 9^{o} 30' to 12^{o} 30' N and Longitude 8^{o} 30' to 9^{o} 42' E), the area is characterized by tropical wet and dry season (Olofin, 2007), a wet season (May-September) and dry season (October-April). Mean annual rainfall ranges between 888.6mm to 960mm while temperature vary from 21^{o}C and 46^{o}C humidity ranges between 20 to 40% (dry season) and 60 to 80% (wet season), KNARDA (2006).

3.2 EXPERIMENTAL EGGS

A total of one hundred and eighty (180) fresh eggs (laid less than 24 hours) were used for the experiment. The eggs were purchased from poultry unit of the Department of Animal Science Bayero University Kano.

3.3 EXPERIMENTAL DESIGN

The experiment was laid in a 3x3 factorial arrangement of a completely randomized design, which include 3 oven temperatures (40, 50 and 60 ^{o}C) and 3 holding times (4, 5 and 6hrs) replicated 4 times each.

3.4 EXPERIMENTAL PROCEDURE

3.4.1 Preparation and Drying of Experimental Eggs

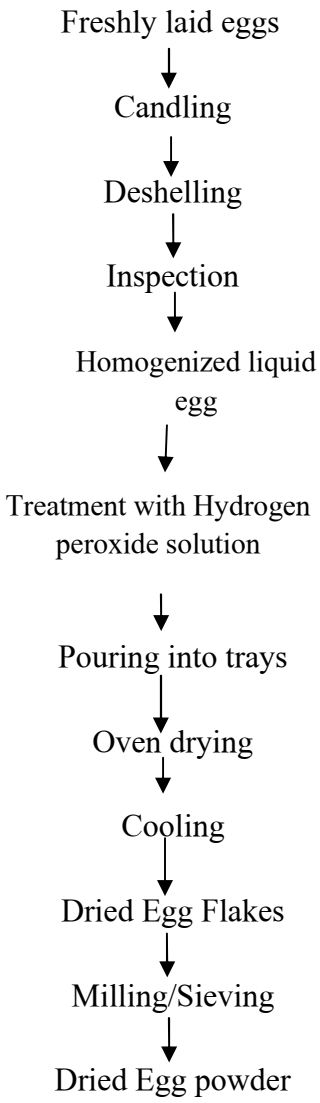

Figure 3: Flow diagram of whole egg processing into powder
Source: Ndife *et al.* (2010)

Fresh eggs (laid less than 24 hours) were used for this trial. The eggs were candled to confirm their freshness. Eggs were deshelled. These were later homogenized with a metal whisk during which 0.5 ml of hydrogen peroxide solution was added to free the products from microorganism and to prevent browning of products as reported by (Desrosier, 1977). The samples were later

oven dried at temperature of 40, 50 and 60^{o}C respectively with holding times of 4, 5 and 6hrs for each temperature and allowed to cool. The egg flakes were scooped, milled and sieved. The egg powders were packed into different plastic films for determination of Nutritional and Functional properties.

3.4.2 Determination of Nutritional Properties

AOAC (1999) was used to determined Nutritional properties. The crude protein was determined using Kjeldahl method. The fat content was determined using reflux soxhlet method. The ash content was determined by igniting 2 g of sample at 550^{o}C in a furnace. The moisture content of the sample was determined by drying 2 g of sample to a constant weight at 100^{o}C.

3.4.3 Determination of Functional Properties

Water absorption capacity (WAC)

Water absorption capacity was determined by method of American Association of Cereal Chemist (AACC) (2000). A g of sample was dispersed in 50 ml of distilled water. The content was mixed for 30 sec. every 10 min using a glass rod and after mixing five times, it was centrifuged at 3000rpm for 20minutes at room temperature. The supernatant was carefully decanted and then content of the tube was drained at a 45^{o} angle for 10minutes before it was weighed. The water absorption capacity was expressed as percentage increase of sample weight.

Oil absorption capacity (OAC)

Oil absorption capacity was determined by the centrifugal method described by Adepeju *et al.* (2014). 1 g of the sample was mixed with 10 ml of pure soya beans oil for 60 seconds, the mixture was allowed to stand for 10 minutes at room temperature, centrifuged at 3000rpm for 30 minutes at room temperature and the oil that separated was carefully decanted and the content of

the tube was allowed to drained at 45^{o} angle for 10 minutes and then weighed. Oil absorption was expressed as percentage increase of the sample weight.

Solubility index (SI)

The solubility index of the sample was determined by the method of Okolie, (1998). 1 g of the sample was suspended in 40 ml distilled water in a clean dry beaker. The suspension was mechanically stirred at a rate sufficient to keep the sample completely suspended. The beaker was placed in a thermostatic water bath with the temperature set at 60^{o}C for 30 minutes with gentle stirring. The stirrer was subsequently removed and rinsed with 10ml distilled water to bring the total water content to 50 ml. The mixture was then centrifuged at 3000rpm for 20 minutes at room temperature. The supernatant was decanted in to evaporating dish. It was then evaporated to dryness at 120^{o}C. The percentage of soluble extract from the sample was calculated on dry weight basis.

Solubility Index (%) = Weight of dried solid after drying x 100

Foaming capacity (FC)

The foaming capacity and foam stability were determined by the method of Suliman *et al.* (2006). 100 ml of distilled water was added to 3 g of the sample. The mixture was homogenized for 5minutes in a blender set at high speed at room temperature and then transfer to a 250ml-measuring cylinder. The volume of foam at 30 seconds was measured and the increase in volume expressed as a percentage foaming capacity (FC).

$$FC\ (\%) = \frac{\text{Volume after whipping} - \text{Volume before whipping}}{\text{Volume before whipping}} \times 100$$

Foam stability (FS)

Foam stability was determined by measuring the decrease in volumes of foam as a function of time up to period of 60 minutes The stable foam volumes were recorded at time intervals of 10, 30, and 60 minutes

$$FS\ (\%) = \frac{\text{Foam volume after time (t)}}{\text{Initial foam volume}} \times 100$$

Emulsifying capacity and emulsion stability (EC and ES)

The procedure described by Suliman *et al.* (2006) was used to determine emulsifying capacity and emulsion stability. Emulsion was prepared with 1 g of sample, 50 ml distilled water and 50 ml of pure soya beans oil at room temperature. The mixture was emulsified for 30 minutes; each emulsified sample was divided equally into 50 ml centrifuge tubes. Content of one tube was directly centrifuged at 3000rpm for 30 minutes at room temperature. While the other centrifuged under the same conditions after heating in water bath at 80^{o}C for 30 minutes and cooled to 15^{o}C. The height of emulsified layer as percentage of the total height of material in the unheated tubes was used to calculate emulsifying capacity and emulsion stability using the following formulas:

$$EC\ (\%) = \frac{\text{Height of emulsion}}{\text{Height of whole layer}} \times 100$$

$$ES\ (\%) = \frac{\text{Height of emulsion layer after heating}}{\text{Height of whole layer}} \times 100$$

3.5 DATA ANALYSIS

Data generated was subjected to Analysis of variance using SPSS Version 16.0 (SPSS, 2007). Differences among means were separated using Least Significant Different (LSD) at 5% level of probability. Correlation and regression analysis were carried out to predict and establish the nature and strength of the relationship between the factors and the variables.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Effects of Temperature on Nutritional Properties of Chicken Eggs Powder

The Effects of temperature on nutritional properties of chicken eggs powder is presented in Table 4. The results showed that there were significant ($p<0.05$) difference among the nutritional properties except for the ash.

Table. 4: Effects of Temperature on Nutritional Properties of Chicken Eggs Powder

	Temperature (^oC)			
Nutritional Properties (%)	40	50	60	SE
Moisture	8.07^a	7.11^b	5.41^c	0.114
Crude protein	17.66^a	18.08^a	11.92^b	0.526
Ash	1.16	1.01	1.14	0.087
Fat	10.50^a	9.50^b	8.57^c	0.193

^{abc} means in the same row with different superscripts differed significantly ($p<0.05$), SE= standard error

The result showed that the moisture (8.07%) and fat (10.50%) contents of treatment 1(40^{o}C) and 2 (50^{o}C) were significantly ($p<0.05$) higher compared to those of treatment 3 (60^{o}C). Significant ($p<0.05$) differences were also observed between temperature of 50^{o}C and 60^{o}C for moisture and fat content. Moisture content decreased with increasing temperature, the same pattern was also observed for fat content.

From the results no significant ($p>0.05$) differences were observed in the crude protein content for temperature of 40^{o}C (17.00%) and 50^{o}C (18.07%). However, both differed significantly ($p<0.05$) compared to temperature of 60^{o}C. Results of ash contents for all the treatments were similar.

4.1.2 Effects of Holding Time on Nutritional Properties of Chicken Eggs Powder.

The effects of holding time on nutritional properties of chicken eggs powder are presented.

Unlike in the effect of temperature on nutritional properties, where fat moisture and crude protein were affected significantly, the effects of holding time on nutritional properties showed that only ash and fat contents were affected significantly ($p<0.05$).

in Table 5. The result shows significant ($p<0.05$) difference on Ash and fat content.

Table. 5: Effects of Holding Time on Nutritional Properties of Chicken Eggs Powder.

	Holding time (hours)			
Nutritional Properties (%)	4	5	6	SE
Moisture	6.82	6.91	6.84	0.114
Crude protein	15.31	15.71	16.14	0.526
Ash	1.19^{a}	0.84^{b}	1.27^{a}	0.087
Fat	9.96^{a}	9.17^{b}	9.41^{ab}	0.193

^{abc} means in the same row with different superscripts differed significantly ($p<0.05$), SE= standard

The result showed that the Ash content on holding time of 4 hours (1.19%) differed significantly ($p<0.05$) compared to holding time of 5 hours (0.84%). No significant ($p>0.05$) difference was observed between the Ash content on holding time of 4 hours (1.19%) and 6 hours (1.27%) with the least (0.84%) Ash content recorded on holding time of 5 hours.

The result also showed that fat content on holding time of 4 hours (9.96%) differed significantly ($p<0.05$) compared to holding time of (9.17%). However, no significant ($p>0.05$) difference was observed in fat content when holding time of 6 hours was compared with 4 and 5 hours. The lowest (9.17%) fat content was recorded on holding time of 5 hours.

No significant ($p>0.05$) difference was observed on moisture and crude protein contents of chicken eggs powder due to holding time.

4.1.3 Interaction Effects of Temperature and Holding Time on Nutritional Properties of Chicken Eggs Powder

The Interaction effects of temperature and holding time on nutritional properties of chicken eggs powder is presented in table 6. The result shows significant ($p<0.05$) difference among all the nutritional properties.

Table.6: Interaction Effects of Temperature and Holding Time on Nutritional Properties of Chicken Eggs Powder.

	Nutritional properties (%)			
Temp.(^{o}C)/HT(hours)	Moisture	Crude protein	Ash	Fat
40x4	8.16^{a}	15.60^{b}	1.19^{ab}	9.94^{ab}
40x5	8.01^{a}	16.06^{b}	0.87^{b}	10.63^{ab}
40x6	8.04^{a}	19.83^{a}	1.42^{a}	10.92^{a}
50x4	7.08^{b}	17.74^{ab}	1.23^{ab}	10.10^{ab}
50x5	7.17^{b}	18.83^{a}	0.73^{b}	8.86^{b}
50x6	7.07^{b}	17.65^{ab}	1.07^{ab}	9.42^{b}
60x4	5.23^{c}	12.60^{c}	1.17^{ab}	9.83^{b}
60x5	5.56^{c}	12.24^{c}	0.91^{b}	8.01^{c}
60x6	5.45^{c}	10.93^{c}	1.33^{ab}	7.89^{c}
SE	0.197	0.911	0.151	0.334

^{abc} means in the same column with different superscripts differed significantly ($p<0.05$), SE= standard error, Temp.= temperature and HT= holding time

The results revealed that the crude protein (19.83%), Ash (1.42%) and fat (10.92%) contents were significantly ($p<0.05$) highest on temperature/holding time of 40^{o}C/6hours while the lowest crude protein (10.93%), Ash (0.87%) and fat (7.89%) contents were observed on temperature/holding time of 60^{o}C/6hours, 40^{o}C/5hours, 60^{o}C/6hours respectively. Moisture

content (8.16%) was significantly ($p<0.05$) highest on temperature/holding time of 40°C/4hours with least (5.23%) moisture content observed on temperature/holding time of 60°C/4hours . The results further indicated that the moisture content decreases with increase in temperature.

4.1.4 Effects of Temperature on Functional Properties of Chicken Eggs Powder

Effect of temperature on functional properties of chicken eggs powder is presented in Table 7. The results showed that there were significant ($p<0.05$) differences among the functional properties except for foaming capacity and solubility index.

Table 7: Effects of Temperature on Functional Properties of Chicken Eggs Powder.

	Temperature (°C)			
Functional Properties (%)	40	50	60	SE
Foaming capacity	18.08	16.17	14.92	1.377
Foam stability	91.18^{b}	94.19^{a}	92.56^{ab}	0.792
Water absorption capacity	48.20^{a}	42.60^{b}	46.74^{a}	1.059
Oil absorption capacity	59.58^{a}	56.57^{b}	57.18^{ab}	0.853
Emulsifying capacity	37.83^{a}	28.00^{b}	19.00^{c}	1.362
Emulsion stability	18.50^{a}	15.17^{b}	12.00^{c}	0.805
Solubility index	85.25	82.58	84.58	1.571

^{abc} means in the same row with different superscripts differed significantly ($p<0.05$), SE= standard error

The result showed that foam stability was significantly ($p<0.05$) highest on temperature of 50°C with the least foam stability (91.18%) observed on temperature of 40°C. Water absorption capacity (48.20%) and oil absorption capacity (59.58%) were significantly ($p<0.05$) highest on temperature of 40°C compared to 50°C with the lowest water absorption capacity (42.60%) and oil absorption capacity (56.57%) recorded on temperature of 50°C. No significant ($p>0.05$) difference was observed in water absorption capacity between the temperature of 40°C and 60°C as well as oil absorption capacity on the temperature of 60°C compared to both 40°C and 50°C.

The results also indicated that the emulsifying capacity (37.83%) and emulsion stability (18.50%) were significantly ($p<0.05$) higher on temperature of 40^{o}C compared to 50^{o}C and 60^{o}C. Similar trend was recorded on temperature of 50^{o}C compared to 60^{o}C with the temperature of 60^{o}C having the least emulsifying capacity (19.00%) and emulsion stability (12.00%). No significant ($p<0.05$) differences were recorded on Foaming capacity and Solubility index of chicken eggs powder due to Temperature.

4.1.5 Effects of Holding Time on Functional Properties of Chicken Eggs Powder.

Effects of holding time on functional properties of chicken eggs powder are presented in Table 8. The result shows significant ($p<0.05$) difference in Foam stability, Emulsifying capacity and Solubility index.

Table. 8: Effects of Holding Time on Functional Properties of Chicken Eggs Powder.

	Holding time (hours)			
Functional Properties (%)	4	5	6	SE
Foaming capacity	16.75	15.58	16.83	1.377
Foam stability	90.87^{b}	93.97^{a}	93.11^{ab}	0.792
Water absorption capacity	45.59	46.38	45.38	1.059
Oil absorption capacity	56.76	58.93	58.27	0.853
Emulsifying capacity	30.33^{a}	28.50^{ab}	26.00^{b}	1.362
Emulsion stability	16.33	14.67	14.67	0.805
Solubility index	88.08^{a}	80.67^{b}	83.67^{ab}	1.571

^{abc} means in the same row with different superscripts differed significantly ($p<0.05$), SE= standard

The results revealed that foam stability (93.97) was significantly ($p<0.05$) highest on holding time of 5 hours compared to 4 hours. However, no significant ($p>0.05$) was recorded on foam stability at holding time of 6 hours when compared to both 4 and 5 hours. Holding time of 4 hours had the least (90.87%) foam Stability.

The result further showed that emulsifying capacity(30.33%) was significantly ($p<0.05$) higher on holding time of 4 hours compared to 6 hours, but no significant ($p>0.05$) difference was observed when holding time of 5 hours was compared to 4 and 6 hours with the least (26.00%) emulsifying capacity observed on holding time of 6hours. Solubility index (88.08%) was significantly ($p<0.05$) higher on holding time of 4 hours compared to 5 hours. However, no significant ($p<0.05$) difference was observed when the solubility index on holding time of 6hours was compared with both 4 and 5 hours, lowest Solubility index was recorded on holding time of 5 hours (80.67%). No significant ($p>0.05$) differences were recorded on foaming capacity, water absorption capacity, oil absorption capacity and emulsion stability of chicken eggs powder due to holding time.

4.1.6 Interaction Effects of Temperature and Holding time on Functional Properties of Chicken Eggs Powder.

The Interaction effects of temperature and holding time on functional Properties of chicken eggs powder is presented in Table 9. The result shows significant ($p<0.05$) difference among the functional properties except for foaming capacity.

Table. 9: Interaction Effects of Temperature and Holding Time on Functional Properties of Chicken Egg Powder

				Functional properties (%)			
Temperature(°C)/HoldingTime(hours)	Foaming capacity	Foam stability	Water absorption capacity	Oil absorption capacity	Emulsifying capacity	Emulsion stability	Solubility index
40x4	20.00	88.02^{b}	46,27^{ab}	59.07^{a}	41.00^{a}	22.00^{a}	86.75^{ab}
40x5	16.25	93.69^{a}	47.99^{ab}	60.81^{a}	39.00^{ab}	17.00^{b}	81.25^{b}
40x6	18.00	91.85^{a}	50.34^{a}	58.87^{a}	33.50^{b}	16.50^{bc}	87.75^{ab}
50x4	16.00	92.37^{a}	42.75^{b}	53.83^{b}	29.00^{b}	15.00^{bc}	91.00^{a}
50x5	16.25	95.65^{a}	40.37^{b}	58.01^{ab}	27.50^{bc}	15.00^{bc}	78.50^{b}
50x6	16.25	94.56^{a}	44.68^{b}	57.88^{ab}	27.50^{bc}	15.00^{bc}	78.25^{b}
60x4	14.25	92.21^{a}	47.76^{ab}	57.40^{ab}	21.00^{c}	12.00^{c}	86.50^{ab}
60x5	14.25	92.56^{a}	51.37^{a}	57.98^{ab}	19.00^{c}	12.00^{c}	82.25^{b}
60x6	16.25	92.92^{a}	41.11^{b}	58.06^{ab}	17.00^{c}	12.00^{c}	85.00^{ab}
SE	2.385	1.372	1.834	1.478	2.359	1.394	2.721

^{abc} means in the same column with different superscripts differ significantly ($p<0.05$), SE= standard error and ns= not significant

The results showed that foam stability for all temperatures and holding time were similar ($p>0.05$) except for temperature of 40°C with holding time of 4hours which differed significantly ($p<0.05$) from the rest of treatments. In the case of water absorption capacity, significant ($p<0.05$) difference were observed only for temperature of 40°C with holding time of 6hours and those of 50°C with holding time of 4-6hours and 60°C with holding time of 6hours. Oil absorption capacity at temperature of 40°C with holding time of 4-6hours was only significantly different ($p<0.05$) with 50°C and holding time of 4hours with 40°C and holding time of 4-6hours recording higher oil absorption capacity. All other temperatures and holding times remain unaffected ($p>0.05$) for oil absorption capacity.

Results on emulsifying capacity followed a different pattern with the other parameters. Here differences existed even within the same temperature regime but different holding time as could be observed for temperature of 40^{o}C and holding time of 4hours and that of 6hours. Temperature of 50^{o}C and 60^{o}C with their corresponding holding time were only affected in the case of 50^{o}C with holding time of 4hours and that of 60^{o}C with all the holding times of 4-6hours. Emulsion stability of 40^{o}C with holding time of 4hours recorded significantly ($p<0.05$) higher value of 22% compared with rest of the temperatures and holding times.

Solubility index within a particular temperature and holding time were not affected ($p>0.05$) except in the case of 50^{o}C where holding time of 4hours (91.00%) was observed to be significantly ($p<0.05$) higher compared to the holding time 5 and 6hours with 78.50 and 78.25% respectively.

4.1.7: Pearson Correlation among Nutritional Properties of Chicken Eggs Powder

Correlation among the nutritional properties of chicken eggs powder is presented in table 10. The result showed no relationship among the nutritional properties of powdered chicken eggs

Table 10: Pearson Correlation among Nutritional Properties of Chicken Eggs Powder

Parameters	Moisture	Crude protein	Ash	Fat
Moisture	1	0.313^{ns}	0.155^{ns}	-0.200^{ns}
Crude protein	_	1	-0.202^{ns}	0.440^{ns}
Ash	_	_	1	0.159^{ns}
Fat	_	_	_	1

ns= not significant

4.1.8: Linear Regression among Nutritional Properties of Chicken Eggs Powder

Table 11 shows result of linear regression among the nutritional properties of chicken eggs powder. The result revealed that temperature had strong negative effect on moisture (R^2=-1.326; p<0.001), Crude protein (R^2=-2.671; p<0.001) and fat (R^2=-0.963; p<0.001). However, no effect was recorded on ash due to temperature and holding time

Table 11: Linear Regression among Nutritional Properties of Chicken Eggs Powder

	Coefficient (R^2)		
Variables	Temperature (^oC)	Holding time (hours)	Constant
Moisture	-1.326***	0.013ns	9.487***
Crude protein	-2.621***	0.414ns	20.131***
Ash	-0.011ns	0.039ns	1.046***
Fat	-0.963***	-0.272ns	11.981***

***p<0.001, ns= not significant and R^2= Regression coefficient

4.1.9: Pearson Correlation among Functional Properties of Chicken Eggs Powder

Correlation among functional properties of powdered chicken eggs is presented in table 12. The result revealed negative correlation (r=-0.510; p<0.01) between foaming capacity and foam stability.

Table 12: Pearson Correlation among Functional Properties of Chicken Eggs Powder

Parameters	Foaming capacity	Foam stability	Water absorption capacity	Oil absorption capacity	Emulsifying capacity	Emulsion Stability	Solubility index
Foaming Capacity	1	-0.510**	0.024^{ns}	-0.112^{ns}	0.115^{ns}	0.401*	0.210^{ns}
Foam stability	_	1	-0.206^{ns}	0.164^{ns}	-0.222^{ns}	-0.396*	-0.341*
Water absorption capacity	_	_	1	0.209^{ns}	0.165^{ns}	0.062^{ns}	0.167^{ns}
Oil absorption capacity	_	_	_	1	0.166^{ns}	0.277^{ns}	-0.378^{ns}
Emulsifying capacity	_	_	_	_	1	0.629**	0.134^{ns}
Emulsion capacity	_	_	_	_	_	1	0.158^{ns}
Solubility index	_	_	_	_	_	_	1

*p<0.05, **p<0.01 and ns= not significant

The results showed positive correlation (r=0.401; p<0.05) between foaming capacity and emulsion stability. However, a negative correlation (r=-0.396; p<0.05) between foam stability and emulsion stability was observed. Similar negetive relationship (r=-0.341; p<0.05) was recorded between foam stability and solubility index as well as oil absorption capacity and solubility index (r=-0.378; p<0.05). On the other hand, positive relationship was observed between emulsifying capacity and emulsion stability (r=0.659; p<0.01) and similar relationship was recorded between foaming capacity and emulsion stability (r=0.401; p<0.05).

4.1.10: Linear Regression among Functional Properties of Chicken Eggs Powder

Table 13 showed the result of linear regression among the functional properties of chicken eggs powder. The result revealed that temperature had strong negative effect on emulsifying capacity (R^2=-9.417; p<0.001) and emulsion stability (R^2=-3.250; p<0.001).

Table 13: Linear Regression among Functional Properties of Chicken Eggs Powder

	Coefficient (R^2)		
Variables	Temperature(^oC)	Holding time(hours)	Constant
Foaming capacity	-1.583^{ns}	0.042^{ns}	19.472***
Foam stability	0.689^{ns}	1.121^{ns}	89.027***
Water absorption capacity	-0.730^{ns}	-0.106^{ns}	47.523***
Oil absorption capacity	-0.884^{ns}	0.753^{ns}	58.250***
Emulsifying capacity	-9.417***	-2.167*	51.444***
Emulsion stability	-3.250***	-0.833^{ns}	23.389***
Solubility index	-0.333^{ns}	-2.208^{ns}	89.222***

*p<0.05, ***p<0.01, ns= not significant and R^2= Regression coefficient

The finding further revealed that emulsifying capacity was affected negatively by holding time (R^2=-2.167; p<0.05). However, no effect was recorded due to temperature and holding time on foaming capacity, foam stability, water absorption capacity, oil absorption capacity and solubility index.

4.2 DISCUSSION

4.2.1 Effects of Temperature and Holding Time on Nutritional Properties of Chicken Eggs Powder.

The Fat, Moisture and Ash values (Table 4-6) compared favorably with the findings of Ndife *et al.* (2010) who reported Fat, Moisture and Ash values of 8.94%, 6.74% and 1.02% respectively for whole eggs oven dried at 44^{o}C for 4 hours, this is also in line with the findings of Kumaravel *et al* (2012). However, the crude protein obtained was lower than 45.2% reported by Ndife *et al.* (2010). The moisture contents were low enough to extend the shelf life of powdered chicken eggs in environment of low humidity (Jay, 2000; Kumaravel *et al.,* 2012).

4.2.2 Effect of Temperature and Holding Time on Functional Properties of Chicken Eggs Powder.

Functional properties determine the application and use of such food materials as ingredients for the production of various food products (Wilcox, 2006). The results obtained indicated that the temperature and interaction of temperature and holding time employed in oven drying had effect on most functional properties. This is in line with the findings of Zoubida *et al.* (2012) who studied effect of heat treatment on egg white proteins and reported significant effect on functional properties. However, holding time in isolation had effect on foam stability, emulsifying capacity and solubility index.

The foaming capacities were lower than the findings of Ndife *et al*. (2010) who reported foaming capacity of 40.00% for whole egg oven dried at temperature of 44^{o}C for 4 hours. However, the Foam stabilities obtained in the study were higher than 59.29% reported by Ndife *et al.* (2010), they were also higher than the values reported by Lomakina and Mikova (2006).

The foaming properties are particularly important in the stability of ice cream and in bread production (Albert, 1997; Wilcox, 2006).

The water and oil absorption capacities compares favorably with that of Ndife *et al.* (2010) who reported water and oil absorption capacities of 62.5% and 38.46% respectively. The water and oil absorption properties exert some useful influence on the rheological, functional and baking quality of their products (Manay and Shadaksharaswamy, 2005). In addition, water and oil absorption properties of the eggs also help to retain moisture and oil during baking and subsequent storage. It enhances both the physical and sensory qualities of their products (Potter and Hotchkiss, 2006).

The emulsifying capacities and emulsion stabilities obtained were lower than 55.00% and 44.86% reported by Ndife *et al.* (2010). However, it compared favorably with values obtained from spray dried egg by Ayo and Okoliko (1999). The temperature/holding time of up to 60^{o}C/6hours employed during oven drying may have played a significant role in low emulsifying capacities and emulsion stabilities observed. The emulsification properties of food materials are necessary for stability of suspension of one liquid in another. The lipid (Lecithin) found mostly in the yolk contributed to emulsification properties (Beuschelberger, 2004). These properties are useful in food such as shortened cake and mayonnaise. The values obtained in this study also reveals that the emulsifying capacities and emulsion stabilities decreases with increases in temperature.

The solubility index, which is one of the physical properties of protein compared favorably with 92.00% reported by Ndife *et al.* (2010). The temperature and holding time of up to 60^{o}C;

6hours employed in the oven drying did not seriously impact negatively on solubility index and their suitability as functional ingredient.

4.2.3 Pearson Correlation and Linear Regression

Correlation is the measure of association between two variables while regression on the other hand is use to predict the dependent variable when the independent variable is known.

Nutritional properties

The pearson correlation among the nutritional properties showed no significant relationship, this in line with the findings of Ndife *et al.* (2010). The linear regression among nutritional properties indicated that temperature had strong negative effect on moisture, crude protein and fat, this statement agreed with the findings of Kumaravel *et al.* (2012). However, no significant effect was recorded on Ash due to temperature. In addition, there were no significant effects on nutritional properties of powdered chicken eggs due to holding time.

Functional properties

The pearson correlation showed negative relationship between foaming capacity and foam stability, foam stability and emulsion stability, foam stability and solubility index as well as oil absorption capacity and solubility index, this is in line with the findings of Ana, (2006). However, it contradicts the findings of Ndife *et al.* (2010). The result further indicated a positive relationship between foaming capacity and emulsion stability, similar trend was observed between emulsifying capacity and emulsion stability. Linear regression showed that temperature had strong negative effect on emulsifying capacity and emulsion stability, this agreed with the

findings of Campbell *et al.* (2005). The results also indicate that holding time had negative effect on emulsifying capacity.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

A study was carried out to determine the effects of temperature and holding time on functional and nutritional properties of powdered chicken eggs. The experiment was laid in 3x3 factorial arrangement in a completely randomized design that involved 3 oven temperatures (40, 50 and 60^{o}C) and 3 holding times (4 5 and 6hours). The result showed that the temperature and holding time employed in oven drying had effects on functional and nutritional properties. Emulsifying capacities, emulsion stabilities and moisture contents decreased with increasing in temperature and holding time. The result also indicated that the drying temperature employed did not adversely affect the nutritional content of oven dried eggs. The pearson correlation showed negative relationship between foaming capacity and foam stability, foam stability and emulsion stability, foam stability and solubility index as well as oil absorption capacity and solubility index. However, positive relationship was recorded between foaming capacity and emulsion stability, similar trend was observed between emulsifying capacity and emulsion stability. The result further showed no significant relationship among nutritional properties. Linear regression showed that temperature had strong negative effect on moisture, crude protein, fat, emulsifying capacity and emulsion stability. The results indicated that holding time had negative effect on emulsifying capacity.

5.2 CONCLUSION

It was concluded that chicken eggs could be powdered at 40-60^{o}C temperature and 6-6hours holding time without adversely affecting the nutritional and most of the functional properties for shelf-life extension.

5.3 RECOMMENDATIONS

Based on the findings of this study, the following recommendations were made:-

1. Excess eggs produced should be processed into powder for shelf-life extension.

2. Powdered eggs could be incorporated as nutritive ingredient in the production of other food products.

3. Further research on eggs drying methods should be conducted to determine the most suitable method.

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APPENDICES

APPENDIX I: UNIANOVA Table for Moisture

Source	DF	SS	MS	F	P
Temp.	2	43.264	21.632	139.602	0.000
H/time	2	0.053	0.026	0.170	0.845
Temp*H/time	4	0.249	0.062	0.401	0.806
Error	27	4.184	0.155		
Total	35	47.746			

APPENDIX II: UNIANOVA Table for Crude Protein

Source	DF	SS	MS	F	P
Temp.	2	264.632	132.316	39.830	0.000
H/time	2	4.111	2.055	0.619	0.546
Temp*H/time	4	48.643	12.161	3.661	0.017
Error	27	89.694	3.322		
Total	35	407.079			

APPENDIX III: UNIANOVA Table for Ash

Source	DF	SS	MS	F	P
Temp.	2	0.159	0.079	0.871	0.430
H/time	2	1.297	0.649	7.113	0.003
Temp*H/time	4	0.183	0.046	0.501	0.735
Error	27	2.462	0.091		
Total	35	4.102			

APPENDIX IV: UNIANOVA Table for Fat

Source	DF	SS	MS	F	P
Temp.	2	22.304	11.152	24.937	0.000
H/time	2	3.916	1.958	4.378	0.023
Temp*H/time	4	10.645	2.661	5951	0.001
Error	27	12.074	0.447		
Total	35	48.939			

APPENDIX V: UNIANOVA Table for Foaming Capacity

Source	DF	SS	MS	F	P
Temp.	2	61.056	30.528	1.341	0.278
H/time	2	11.722	5.861	0.258	0.775
Temp*H/time	4	27.278	6.819	0.300	0.876
Error	27	614.500	22.759		
Total	35	714.556			

APPENDIX VI: UNIANOVA Table for Foam Stability

Source	DF	SS	MS	F	P
Temp.	2	54.460	27.230	3.614	0.041
H/time	2	61.487	30.744	4.080	0.028
Temp*H/time	4	28.845	7.211	0.957	0.447
Error	27	203.429	7.534		
Total	35	348.221			

APPENDIX VII: UNIANOVA Table for Water Absorption Capacity

Source	DF	SS	MS	F	P
Temp.	2	202.507	101.253	7.525	0.003
H/time	2	9.803	4.901	0.364	0.698
Temp*H/time	4	277..635	69.409	5.158	0.003
Error	27	363.311	13.456		
Total	35	853.256			

APPENDIX VIII: UNIANOVA Table for Oil Abs0rption Capacity

Source	DF	SS	MS	F	P
Temp.	2	54.944	27.472	3.145	0.059
H/time	2	29.600	14.800	1.694	0.203
Temp*H/time	4	25.822	6.456	0.739	0.574
Error	27	235.878	8.736		
Total	35	346.245			

APPENDIX IX: UNIANOVA Table for Emulsifying Capacity

Source	DF	SS	MS	F	P
Temp.	2	2129.556	1064.778	47.835	0.000
H/time	2	113.556	56.778	2.551	0.097
Temp*H/time	4	45.111	11.278	0.507	0.731
Error	27	601.000	22.259		
Total	35	2889.222			

APPENDIX X: UNIANOVA Table for Emulsion Stability

Source	DF	SS	MS	F	P
Temp.	2	253.5561	126.778	16.300	0.000
H/time	2	22.222	11.111	1.429	0.257
Temp*H/time	4	52.444	13.111	1.686	0.182
Error	27	210.000	7.778		
Total	35	538.222			

APPENDIX XI: UNIANOVA Table for Solubility Index

Source	DF	SS	MS	F	P
Temp.	2	46.222	23.111	0.780	0.468
H/time	2	334.056	167028	5.639	0.009
Temp*H/time	4	226.278	56.569	1.910	0.138
Error	27	799.750	29.620		
Total	35	1406.306			

APPENDIX XII: Pearson Correlation for Nutritional Properties of Powdered Eggs

	Moisture	CP	Ash	Fat
Moisture	1.000			
P-Value	-			
CP	0.313	1.000		
	0.072	-		
Ash	0.155	-0.202	1.000	
	0.383	0.252	-	
Fat	-0.200	0.044	0.159	1.000
	0.256	0.803	0.370	-

APPENDIX XIII: Pearson Correlation for Functional Properties of Powdered Eggs

	FC	FS	WAC	OAC	EC	ES	SI
FC	1.000						
P-Value	-						
FS	-0.510	1.000					
	0.002	-					
WAC	0,024	-0.206	1.000				
	0.889	0.228	-				
OAC	-0.112	0.164	0.209	1.000			
	0.516	0.338	0.221	-			
EC	0.155	-0.222	0.165	0.166	1.000		
	0.368	0.193	0.335	0.334	-		
ES	0.401	-0.396	0.062	0.277	0.629	1.0	
	0.015	0.017	0.718	0.102	0.000	-	
SI	0.210	-0.341	0.167	-0.378	0.134	0.158	1.000
	0.220	0.042	0.331	0.023	0.435	0.356	-

APPENDIX XIV: Linear Regression of Moisture

Predictor variables	**Coefficient**	**Standard Error**	**T**	**P**
Constant	9.487	0.247	38.474	0.000
Temperature	-1326	0.084	-15.829	0.000
H/time	0.013	0.084	0.154	0.878

APPENDIX X V: Linear Regression of Crude Protein

Predictor variables	**Coefficient**	**Standard Error**	**T**	**P**
Constant	20.131	1.614	12.471	0.000
Temperature	-2.621	0.548	-4.780	0.000
H/time	0.414	0.548	0.755	0.456

APPENDIX X VI: Linear Regression of Ash

Predictor variables	Coefficient	Standard Error	T	P
Constant	1.046	0.211	4.959	0.000
Temperature	-0.011	0.072	-0.157	0.876
H/time	0.039	0.072	0.541	0.592

APPENDIX X VII: Linear Regression of Fat

Predictor variables	Coefficient	Standard Error	T	P
Constant	11.981	0.522	22.947	0.000
Temperature	-0.963	0.177	-5.430	0.000
H/time	-0.272	0.177	-1.534	0.135

APPENDIX X VIII: Linear Regression of Foaming Capacity

Predictor variables	Coefficient	Standard Error	T	P
Constant	19.472	2.676	7.277	0.000
Temperature	-1.583	0.909	-1.742	0.091
H/time	0.042	0.909	0.046	0.964

APPENDIX X VIX: Linear Regression of Foam Stability

Predictor variables	Coefficient	Standard Error	T	P
Constant	89.027	1.832	48.597	0.000
Temperature	0.689	0.622	1.107	0.276
H/time	1.121	0.622	1.801	0.081

APPENDIX XX: Linear Regression of Water Absorption Capacity

Predictor variables	Coefficient	Standard Error	T	P
Constant	47.523	3.032	15.673	0.000
Temperature	-0.730	1.030	-0.709	0.483
H/time	-0.106	1.030	-0.103	0.919

APPENDIX XXI: Linear Regression of Oil Absorption Capacity

Predictor variables	Coefficient	Standard Error	T	P
Constant	58.250	1.853	31.431	0.000
Temperature	-0.884	0.630	-1.405	0.170
H/time	0.753	0.630	1.197	0.240

APPENDIX XXII: Linear Regression of Emulsifying Capacity

Predictor variables	Coefficient	Standard Error	T	P
Constant	51.444	2.664	19.313	0.000
Temperature	-9.417	0.905	-10.407	0.000
H/time	-2.167	0.905	-2.395	0.022

APPENDIX XXIII: Linear Regression of Emulsion Stability

Predictor variables	Coefficient	Standard Error	T	P
Constant	23.389	1.713	13.656	0.000
Temperature	-3.250	0.582	-5.586	0.000
H/time	-0.833	0.582	-1.432	0.161

APPENDIX XXIV: Linear Regression of Solubility Index

Predictor variables	Coefficient	Standard Error	T	P
Constant	89.222	3.752	23.779	0.000
Temperature	-0.333	1.275	-0.262	0.795
H/time	-2.208	1.275	-1.733	0.092