COMPARATIVE EVALUATION OF DIFFERENTLY PROCESSED WHOLE EGG POWDER

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ZARIA, NIGERIA

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DEPARTMENT OF ANIMAL SCIENCE,
FACULTY OF AGRICULTURE,
AHMADU BELLO UNIVERSITY,
ZARIA, NIGERIA

NOVEMBER, 2018

DECLARATION

I declare that this thesis titled "COMPARATIVE EVALUATION OF DIFFERENTLY PROCESSED WHOLE EGG POWDER" has been carried out and written by me in the Department of Animal Science, Ahmadu Bello University, Zaria, under the supervision of Prof. T.S. Olugbemi and Dr. E.Z. Jiya. The information derived from the literature has been duly acknowledged in the text and list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other Institution.

_____ _____

Esther Ifeoluwa DARAMOLA Date

CERTIFICATION

This thesis entitled "COMPARATIVE EVALUATION OF DIFFERENTLY PROCESSED WHOLE EGG POWDER" by Esther Ifeoluwa DARAMOLA meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this thesis to God-the Author and Finisher of my Faith, My beloved Parents and to all the Heros in the field of Animal Science.

ACKNOWLEGDEMENT

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ABSTRACT

Egg is a nutrient dense food. The cylical egg glut characterized by egg spoilage, quality deterioration and wastage imparts negatively on poultry farmers. Powdered dried egg provides a convient alternative to this problem. The focus of this study was to compare and evaluate differently processed whole eggs into powder farm. Two experiments were conducted to evaluate the potential of whole egg powders made from different processing methods. The first compared the yield, proximate composition, microbiological load, functional properties and organoleptic attributes of fried egg and cake from differently processed (Spray dried-commercial, Freeze dried and Dehydrated) whole egg powders. The second assessed the effect of egg age on the proximate composition, microbiological load, functional properties and organoleptic attributes of cookies and cake made from dehydrated whole egg powder. The treatments in experiment one were the Spray Dried, Freeze Dried and Dehydrator Dried Whole Egg Powders represented as SDWEP, FDWEP and DDWEP respectively. Thirty five eggs each were used to produce the FDWEP and DDWEP while the SDWEP was obtained from United State of America. The Experimental design was a completely randomized design. Powder percentage yield of 1000g raw eggs (26.7%) and crude protein (52.78%) was highest ($P<0.05$) from SDWEP. *Salmonella spp* observed in raw eggs was destroyed by heat from the processing methods in the whole egg powders. The microbial load was within the 2cfu/g acceptable limits. Functional properties were generally significantly ($P<0.05$) higher for raw eggs than the whole egg powders, however with no significant ($P< 0.05$) differences for foaming capacity, foaming stability, emulsifying activity, swelling capacity and bulk density. Fried eggs from raw eggs generally had the highest ($P<0.05$) organoleptic rating but did not differ from SDWEP, FDWEP for texture and taste, SDWEP and DDWEP for flavour, SDWEP and DDWEP for general

acceptability. All whole egg powders compared equally for all indices. Cake colour differed significantly ($P<0.05$) with Raw, SDWEP and DDWEP rating equally (5.50, 4.40, 4.30 respectively). In experiment two, treatment (weeks 1, 2, 3, 4) had a significant ($P<0.05$) effect on the crude protein indices of raw eggs with a decline from 50.96 to 42.91% as the eggs aged. Microbial load were within permissible limits. *Salmonella spp* and *E. coli* were absent. Foaming capacity declined (37.66-28.22%) with age but was only significant at the 4^{th} week. Emulsifying capacity, water absorption, water and oil retention capacity with values of 29.85%, 0.86g, 0.52g and 0.52g respectively were best ($P<0.05$) at the second week. The crude protein and ether extract of the whole egg powder declined from 50.96-42.91% and 5.01-3.87% respectively as eggs aged from one to four weeks. The Microbial load was within permissible limits. Foaming capacity (30.41%), emulsifying capacity (29.41%), swelling capacity (118.74%), water and oil absorption (0.29, 0.29%) were best ($P<0.05$) at weeks 2, 1 and 3 respectively. Cookies and cakes produced from whole egg powders of one to four weeks of age were generally accepted without specific preference. This study concludes that whole egg powders produced by spray, freeze or dehydrator methods are generally accepted and serve as good alternatives to fresh eggs in addition to their use in the confectionary industry not compromising the final product quality. Dehydrator dried whole egg powder from 3 week old eggs may also be safely used in the confectionary industry without health or product quality disadvantages.

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CHAPTER ONE

1.0 INTRODUCTION

Agriculture in Nigeria has over the last few years received increasing attention with both Federal and State Governments encouraging the Nigerian populace especially the youth to embrace agriculture as a profession and a means out of the current recession (African Economic Outlook, 2012).

USDA (2013) as cited by Heise *et al.* (2015) reported that of the various components of animal husbandry, poultry farming is the most popular and probably lucrative. Nigerian Federal and State governments are investing in poultry production. Egg production plays a vital role in poultry farming and has been on the increase with various government programmes such as "Feed the School Children" encouraging more people to embark on poultry production. Eggs are laid by female animals of many different species, including birds, reptiles, amphibians, mammals, and fish, however among other avian the most popular choice for egg consumption are chicken eggs. They are a cost effective animal protein with a potential to contribute to food and nutrition security and generate rural household livelihoods (Lannotti *et al.*, 2014) and are considered to be nature's most nearly perfect food for mankind and are therefore used as the reference protein for assessing protein quality of other proteins. Eggs are also sources of vitamins A, D, B_1 (Olomu, 2011).

Eggs in general are one of the cornerstones of baked goods and cooking with breads, cakes, bakery mixes, and an assortment of desserts owing much of their unique texture, taste and moisture to the egg. Eggs are low in saturated fats and are good sources of high quality protein and varying amounts of 13 essential vitamins and minerals, including Vitamin A, B_{12} and folate hence them being termed as a "nutritional powerhouse". Eggs are extremely perishable and must

be kept refrigerated as they have a relatively short shelf life. They are also delicate and bulky thereby having increased risk of breakage during transportation. (Lauber, 2007; 2017)

The cyclical egg glut in Nigeria characterized by egg spoilage, egg quality deterioration, and wastage in the process of transporting excess eggs which eventually results in loss of inputs to poultry farmers which spans for about 3 months /year is on the increase as more individuals embark on poultry production in order to alleviate poverty and unemployment. Poultry farmers across the nation have cried out that the glut being experienced was likely to discourage farmers from further production and cause a collapse in the poultry sector (African Economic Outlook, 2012). The situation has not changed even as at today (Okojie, 2017).

Powdered, dried eggs provide a convenient alternative to fresh eggs and add quality and consistent performance to the list of attributes. In addition, dry egg products can be stored up to a year or longer under proper storage conditions, the risk of bacterial contamination due to improper handling is significantly reduced as well as the cleanup time. Powdered, dried eggs are a solution to bulkiness and fragility of fresh eggs as well as storage challenges as they can be stored up to a year or longer under proper storage conditions, (Jay, 2000). For bakers, powdered egg products provide consistency from batch to batch and are always ready. Egg solids blend well with other dry ingredients and can be used immediately without cracking or thawing (Anonymous 2010) and when it comes to using eggs as a source of protein for dietary supplement or muscle gain, eggs rate as the cheapest source of high quality protein and egg powder further reduce this cost (Heymann, 2015). It an ideal alternative for individuals who cannot consume dairy products due to lactose intolerance as it is lactose free (Greenfield, 2013).

Several processing and preservation methods like spray drying, tray drying and freeze drying techniques have been adopted with advantages and disadvantages on the qualities of the products (Potter and Hotchkiss, 2006). The use of dehydrator is another method for making egg powder with both dehydrated and freeze dried food having similar benefits, including a potentially far longer shelf life than home canned food as they are both stable products when stored in a cool, dry place (Dodrill, 2014).

Powdered eggs are popular in several developed countries with little or no differences reported between fresh eggs and egg powder however, Nigeria despite her achievement in agriculture most especially in poultry-egg production, has a limited or practically no provision for handling processing of eggs. This study explored some adaptable processes of transforming fresh eggs into whole egg powder thereby extending its shelf-life while still maintaining its richness.

1.1 Problem Statement

For about a decade now, a huge attention has been shifted to poultry farming most especially for egg production especially in the light of the current recession. However, farmers have been bedeviled with a major setback in the management of eggs after production resulting from higher supply and lower demand thereby leading to egg-glut. Egg glut over a period of time results in a compromise of egg quality (deterioration and spoilage). The attempt to transport excess eggs from one location to another in times of glut has its attendant problem of egg breakage and deterioration of the internal quality thereby enhancing micro-organism penetration.

1.2 Justification

Several challenges posed by egg-glut so far have brought losses in place of gain to both small and large-scale producers. Therefore, this research focused on how to manage glut conditions by exploring methods of processing raw eggs to egg powder in order to extend its shelf-life as well

as make transportation convenient without fear or risk of wastage. The egg powder would also be a useful resource both in homes and in the confectionary industry.

1.3 Objectives

The broad objective of this research was to conduct a comparative evaluation of whole egg-powder produced from different processing methods.

Specific objectives were to:

i. Produce whole egg powder through freeze drying and dehydrator processing methods.

ii. Compare the yield, proximate, microbial and functional properties of a commercial whole egg-powder with freeze dried and dehydrator processed whole egg powders.

iii. Compare the organoleptic properties of fried egg and cake prepared from freeze dried, dehydrator processed, commercially whole egg powders and raw egg.

iv. Determine the effect of egg age on the proximate, microbial and functional properties of whole egg powder processed by dehydrator method.

v. Determine the effect of egg age on the organoleptic properties of cookies and cake prepared from whole egg powder processed by dehydrator method.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Eggs

Eggs are laid by female animals of many different species, including birds, reptiles, amphibians, mammals, and fish, some of which have been eaten by humans for thousands of years (Kiple, 2007). Bird and reptile eggs consist of a protective eggshell, albumen (egg white), and vitellus (egg yolk), contained within various thin membranes. The most popular choice for egg consumption arechicken eggs. Other popular choices for egg consumption are duck, quail, roe, and caviar.

Eggs are known to supply the best proteins besides milk (Vaclavik and Christian, 2008). They are one of the most versatile and near perfect foods in nature. It is rich in protein, amino-acids, vitamins and most mineral substances, the yolk and white components are all of high biological value and are readily digested. Eggs play important culinary roles and are therefore prepared into different dishes.

2.2 Egg Production Worldwide in Nigeria

Chickens and other egg-laying creatures are widely kept throughout the world, and mass production of chicken eggs is a global industry. In 2009, an estimated 62.1 million metric tons of eggs were produced worldwide from a total laying flock of approximately 6.4 billion hens. The high population growth in Africa's high growth in population (World Health Organization 2010) and growing income has led to demand for eggs and poultry meat which has significantly increased in recent years across large parts of the continent (Heise *et al.*, 2015). USAID (United States Agency for International Development), estimated this trend is very likely to continue

over the next few years. Therefore, the consumption of poultry and eggs will increase by 200% between 2010 and 2020 for at least some countries in sub-Saharan Africa (USDA, 2013).

In recent times, Nigeria being one of the largest countries in Africa, with a total geographical area of 923,768 square kilometers (Manyong *et al.,* 2005) with estimated population has 174.5 million people in 2013, and its population growth rate is 3% per annum (USDA, 2013) has not reduced in poverty or created much-needed jobs. Unemployment is still very high, and more than 60% of the population lives below the poverty line (African Economic Outlook 2012).

The Nigerian poultry industry in particular has been rapidly expanding in recent years and is therefore one of the most commercialized (capitalized) subsectors of Nigerian agriculture (Adene and Oguntade, 2006; USDA, 2013). The popularity of poultry production can be explained by the fact that poultry has many advantages over other livestock. Poultry birds are good converters of feed into useable protein in meat and eggs. The production costs per unit remain relatively low, and the return on investment is high. Egg as one of the major products of poultry production, are more affordable for the common person than other sources of animal protein (Aboki *et al*., 2013).

2.3 Composition of Eggs

The major and physical components of eggs include eggshell, egg membrane, egg white, egg yolk and air cell. FAOSTAT (2015) reported that both the white and the yolk are complex mixtures and much uncertainty exists as to the nature of their constituents. They contain several appreciable proteins, and several triglycerides and phosphatides in the yolk. Phosphorus exists in protein, phosphatide, and inorganic combination, the organic phosphorus being present in such

considerable amount as to cause a marked excess of acids over bases on ashing. The chemical composition of the egg is as shown in Table 2.1.

Table 2.1: Physical and nutritional composition of eggs

Component (Unit)	Amount	Component (Unit)	Amount
Egg shell (%)	10.5	Calcium (mg)	56.0
Egg yolk (%)	31	Magnesium (mg)	12.0
Egg white (%)	58.5	Iron (mg)	2.1
Water (g)	74.5	Phosphorus (µg)	180.0
Energy (Kcal)	162	Zinc (mg)	1.44
Protein (g)	12.1	Thiamine (mg)	0.09
Carbohydrates (g)	0.68	Riboflavin (mg)	0.3
Lipids (g)	12.1	Niacin (mg)	0.1
Saturated fatty acids (g)	3.3	Folic acid (µg)	65.0
Monounsaturated fatty acids (g)	4.9	Cyanocobalamin (µg)	66.0
Polyunsaturated fatty acids (g)	1.8	Pyridoxine (mg)	0.12
Cholesterol (mg)	410	Retinol equivalents (µg)	227.0
Iodine (µg)	12.7	Potassium (mg)	147
Tocopherols (µg)	1.93	Carotenoids (µg)	10
Selenium (µg)	10	Cholecalciferol (µg)	1.8

Source: Nutrients (2015) as cited by Ubani (2018)

2.3.1 Eggshell

Egg shell color is caused by pigment deposition during egg formation in the oviduct and can vary according to species and breed, from the more common white or brown to pink or speckled blue-green. In general, chicken breeds with white ear lobes lay white eggs, whereas chickens with red ear lobes lay brown eggs (Hincke *et al.*, 2012). Although there is no significant link between shell color and nutritional value, there is often a cultural preference for one color over another. A report by Omi and Ezawa (1998) and Brun *et al.* (2013) described chicken eggshell as comprised of Calcium (Ca) and a few protein sources, which is available for home use as well as supplementation.

2.3.2 Egg Membrane

The membrane is a clear film lining the eggshell, visible when one peels a boiled egg. Eggshell membrane is primarily composed of fibrous proteins such as collagen type I. From the reports of Guarderas *et al.* (2016), egg membrane is a highly collagenized tissue found to be 90% protein by weight. His results further described egg membrane as a wound healing cure. Traditional folk remedy of dressing a wound with chicken-egg membrane treatment (the outer shell membrane) appears to accelerate the early stages of wound healing. The authors' data support the idea that the application of a chicken-egg membrane to a wound might provide benefit over an uncovered wound.

2.3.3 Egg White

Karadas *et al.* (2006) reported that the clear liquid (also called the albumen or the glair) contained within an egg was named egg white. It consists primarily of about 90% water into which is dissolved 10% proteins (including albumins, mucoproteins, and globulins). In chickens it is formed from the layers of secretions of the anterior section of the hen's oviduct during the

passage of the egg (USDA, 2011). It forms around either fertilized or unfertilized yolks. The primary natural purpose of egg white is to protect the yolk and provide additional nutrition for the growth of the embryo. Unlike the yolk, which is high in lipids (fats), egg white contains almost no fat and the carbohydrate content is less than 1%. Egg white has many uses in food, and many others, including the preparation of vaccines such as those for influenza (Evenepoel *et al.*, 1998). The egg as a whole is considered as a good source of protein and lipids, but egg white mainly consists of water (88%) and protein (11%) and it is lacking in lipids (Stadelman and Cotterill, 2001; Abeyrathne *et al.*, 2013). Ovomucin is a highly glycosylated protein and approximately 33% of ovomucin is made up of carbohydrates (Omana *et al.*, 2010). Therefore, ovomucin can be considered a good source of nutrients that can supply 2 vital nutrients, protein and carbohydrates. Ovalbumin is the major egg white protein, has well-balanced amino acid composition, and thus can be used as an excellent protein source for many food items. The rest of the egg white proteins also are considered to be good sources of essential amino acids.

2.3.4 Egg Yolk

The yolk in a newly laid egg is round and firm. As the yolk ages, it absorbs water from the albumen, which increases its size and causes it to stretch and weaken the vitelline membrane (the clear casing enclosing the yolk). The resulting effect is a flattened and enlarged yolk shape. Yolk color is dependent on the diet of the hen; if the diet contains yellow/orange plant pigments known as xanthophylls, then they are deposited in the yolk, coloring it. Lutein is the most abundant pigment in egg yolk (Schaafsma and Beelen, 1999). A colorless diet can produce an almost colorless yolk. Yolk color is for example, enhanced if the diet includes products such as yellow corn and marigold petals.

2.4 Nutritional Value of Eggs

Chicken eggs, the most commonly eaten eggs, /8provide 155 calories (kcal) of food energy and 12.6 g of protein in a 100 gram serving. Eggs (boiled) supply several vitamins and minerals as significant amounts of the Daily Value (DV), including vitamin A (19% DV), riboflavin (42% DV), pantothenic acid (28% DV), vitamin B_{12} (46% DV), choline (60% DV), phosphorus (25% DV), zinc (11% DV) and vitamin D (15% DV) (table per 100 gram serving of a hard-boiled egg). A yolk contains more than two-thirds of the recommended daily intake of 300 mg of cholesterol. Eggs are a conventional food containing nutrients that play fundamental roles beyond basic nutrition, their promotion as functional foods should be considered (Herron *et al.,* 2004). Eggs are of particular interest from a functionality point of view, because they offer a moderate calorie source (about 150 kcal/100 g), a protein of excellent quality, great culinary versatility and low economic cost (Carrillo *et al.,* 2012) which make eggs within reach to most of the population. Eggs are also relatively rich in fat-soluble compounds and can, therefore, be a nutritious inclusion in the diet for people of all ages and at different stages of life. In particular, eggs may play a particularly useful role in the diets of those at risk of low-nutrient intakes such as the elderly, pregnant women and children (Natoli *et al.,* 2007).

The nutritional composition of raw chicken eggs as cited by Ruxton *et al.* (2010) is shown in Table 2.2.

Table 2.2: The nutritional composition of chicken (raw) eggs

Nutrient	Nutrient content per 100 g	Per medium egg (58 g)[a]	Cut-off for ‘‘source’’ Claim (15% RDA)	RDA
Energy (kcal)	151	78	–	–
Protein (g)	12.5	6.5		
Carbohydrate (g)	Trace	Trace	–	–
Fat (g)	11.2	5.8	–	–
Cholesterol (mg)	391	225	–	–
Retinol equiv. (mg)	190	98	120	800
Vitamin D (mg)	1.6	0.9	0.75	5
Riboflavin (mg)	0.47	0.24	0.21	1.4
Folate (mg)	50	26	30	200
Vitamin B12 (mg)	2.5	1.3	0.38	2.5
Choline (mg)	160	83.2	82.5	550
Biotin (mg)	20	10	7.5	50
Phosphorus (mg)	200	104	105	700
Iron (mg)	1.9	0.99	2.1	14
Zinc (mg)	1.3	0.68	1.5	10
Iodine (mg)	53	28	22.5	150
Selenium (mg)	11	5.7	8.25	55

Notes: Values in italic meet the minimum requirement to be labelled as ‘‘a source’’ according to EU regulations (European Parliament and Council, 2006; European Commission, 2008), except for protein which can be labelled ‘‘high’’ because more than 20 per cent of the energy value is protein (European Parliament and Council, 2006); RDA, recommended daily allowance; refers to edible portion of an average 56 g egg

Source: compiled by Ruxton*et al.* (2010)

2.4.1 Factors Influencing Egg Nutritional Quality

Several factors are capable of influencing the nutritional composition of egg. One of these is the diet of laying hens. Chicken eggs that are especially high in omega-3fatty acids are produced by feeding hens a diet containing polyunsaturated fats from sources like fish oil, chia seeds or flaxseeds (Evenepoel, *et al.,*1998*)*. Pasture-raised free-range hens, which forage for their own food, also produce eggs that are relatively enriched in omega-3 fatty acids compared to cage-raised chickens (USDA, 2007). A 2010 USDA study determined there were no significant differences of macronutrients in various chicken eggs (Weggemans *et al.,* 2001).

Egg proteins, fats, sugars, vitamins, and minerals form a nutritional complex facilitating the development of the chicken. Another emphasized factor is the weight and regularity of shape which are said to be the two most significant parameters, as they determine the rate of loss during automated processing. The shape of eggs is important in terms of packaging and industrial processing. The shape is determined by the ratio between the longer and the shorter axes of the egg (Ledvinka *et al.,* 2012).

Types of farming systems which includes battery-cages, deep litter or free-range, have a significant impact on eggs quality, particularly the shell. Comparing egg production parameters obtained from hens farmed in conventional cages, furnished cages and non-cage housing systems, it is evident that total egg mass output is lowest using non-cage systems (EFSA, 2006). A report by Vanden Brand *et al.* (2004) stated that eggs from caged hens demonstrate better shell quality, especially in terms of strength and thickness, higher egg shape index values, yolk index and albumen quality expressed especially by Haugh units, compared to eggs from hens raised in deep-litter or on free-range farms unlike the deep-litter and free-range farming, eggs are

subjected to greater levels of bacterial pollution and show a greater incidence of surface defects. It has been found that the number of non-standard eggs was several times higher in cases of free-range and deep litter farming compared to battery-cage farming. The increased numbers of soiled eggs are correlated to the numbers of eggs laid on the floor, as is the case in all floor and free-range systems (Klecker *et al*., 2003).

2.5 Egg Powder

The modern method of manufacturing powdered eggs was developed in the 1930s by Albert Grant and C. London. Eggs were imported from china by cake manufacturers and they discovered it was 75% water content in the egg. An experimental freeze drying plant was built and tried. Then a factory was set up in Singapore to process Chinese egg. Turabi *et al.* (2008) reported that as war approached, Grant transferred his dried egg facility to Argentina. In wartime the most difficult food to get are the body-builders. Dried eggs build muscles and repair tissue in just the same way as do chops and steaks; and are better for health protection so dried eggs made for any shortage of other body-builders such as meat, fish, cheese and milk. Commercial Egg white powder contains 82% protein. Egg white powder contains high proportion of protein (62.04%) and fat (7.17%) (Ndife *et al.*, 2010).

Egg powder was used in the United Kingdom during World War II for rationing. Powdered eggs are also known as dried eggs, and colloquially during the period of rationing in the UK, as Ersatz eggs. The current technological procedures of egg powder production is to wash, break, filter and pasteurize the egg liquid produced, dry them whole or into their various components of egg yolk and egg white (Jay, 2000).

Powdered egg is used as an emulsifying agent in emulsion formulations, increasing their stability, properties and economy (IgnÁrio *et al*., 2007). The EuroAisa Bakery Report (2005) reported the importance whole egg powder in bakery Products as a major participant to opportunities for employment and economic growth. Egg powder use in this sector caused an increase in competition and evolving expectations of the consumer as regard convenience and health, has continued to effect trend of market. Consumers of today are expecting improvements and developments in manufactured product (Asghar, 2012).

2.5.1 Advantages of Egg Powder

With proper storage conditions (cool, dark, dry), dried eggs have a longer shelf life than fresh whole egg. Egg powder preserves and prolongs shelf life, gives a fresh appearance, is convenient, tasty, crunchy, and healthy (Abdullah, 2008). The transport and storage of powdered egg is less costly and requires less space at low moisture content and is less susceptible to microbial growth. In powdered form, the eggs can be added to baked recipes without the need to mix them with a liquid ahead of time. The transport and storage of powdered egg is less costly and requires less space at low mustier content.

Prasad *et al*. (2004) suggested that biscuits enriched with spray-dried egg powder can form a good substitute instead of shell eggs for armed personnel stationed in remote areas. Furthermore, spray dried egg powder has great importance for food industry with respect to handling and hygienic aspects. They further stated that dried eggs can be used in a number of baking, cooking, and dry-mix recipes. They have the same great taste as fresh eggs but are much easier to transport. For outdoor recreation and travel, powdered eggs are the perfect choice as a backpacking breakfast. Egg cans or pouches can be easily stored in camping gear, tackle box, backpack and will provide a nourishing meal any time of day. A nutritious anytime meal or

snack, powdered eggs are easy to prepare and travel well. They serve as emergency food supply for a variety of reasons. Dehydrated eggs can be enjoyed on their own for breakfast, lunch, or dinner. They provide the necessary protein to sustain during tough times, including severe weather events, emergency evacuations, and even unexpected job loss (Prasad *et al.* 2004).

2.6 Uses and Nutritional Benefits of Eggs Both in Raw and Powdered Forms

Generally, eggs are vital sources of Vitamin A, protein and iron and hence its consumption from poultry meat and eggs can prevent their deficiency (Moreki *et al.*, 2010). Protein is essential for both growth and maintenance of muscle mass. Iron also has many physiological roles such as support of the immune system and transport of oxygen, while Vitamin A plays a role in vision and immunity among other functions (Roy *et al.*, 2012). Eggs perform multiple functions in making and processing of foods as they emulsify as well as add color, tenderness and flavor.

2.6.1 Confectionary Industry

These natural properties of whole egg both in raw or dried forms are useful in bakery foods, bakery mixes, mayonnaise and salad dressings, confections, ice cream, pastas and many convenience foods (Stadelman and Cotterill, 1995). Egg powder has been used in many food products such as bakery products, confectionaries and meat products for different purposes such as emulsifier, and texture and nutrition enhancers to increase protein and fat content. Eggs helps to stabilize emulsion, retaining gas produced by the leavener. Egg also give little but significant colour and flavor and enrich nutritional values of cakes (DesRochers *et al.*, 2003).

As the role of powder form is mainly to preserve and prolong shelf life, most powder food are not consumed directly but sometimes mixed with water, food producer who use egg as raw materials tend to use powder egg. In addition, to eliminate crystallization and ensure a smooth texture, eggs are included in frozen dairy products (BEPA Food processing, 2009).

2.6.2 Medicine and Production of Vaccines

Sialic acid derivatives from egg yolk are known to be involved in brain (neuron) functions and are also important in protecting infants from various diseases. Egg Yolk Phospholipids (EYPLs) have been defined as a natural cell membrane-refreshing nutrient. These and sialyl oligosaccharides attract attention from pharmacological and food chemical industries because of their potential biological functions. Eggs have multiple uses in biotechnology, chemical, food, pharmaceutical and art (painting and photography) industries (Messier, 1991; Germadios *et al*., 1996 and Froning, 2008).

Successful results have been obtained by feeding piglets (and rabbits) egg yolk powder containing anti-*E. coli* antibodies. This serves as a protection against the pathogenic effects of *E. coli* which causes usually fatal diarrhea in early weaned piglets. Fertile eggs are used to manufacture many vaccines (including influenza shots), as a source of purified protein and as an aid in the preservation of bull semen for artificial insemination. These have recently been registered in the European Community as a Novel Food. Several authors have reported the roles played by eggs as antimicrobial, antioxidants, antiviral, antibiotics, anticancer, antihypertensive treatments and activities varying from different components of the egg. Lysozyme for example, which is found in egg albumen is effective for a wide range of viral skin diseases: herpetic lesions, verruca vulgaris and plantaris, aphtous stomatitis, polymorphous exudative erythema, molluscumcontagiosum (de Douder and Morias, 1974; Fichtali*et al*., 1994; Stadelman and Cotterill, 1995; Germadios *et al*. 1996; Coleman, 1998; Abdullahi, 2016).

Egg yolk is commonly used as a protectant in semen extenders to preserve mammalian spermatozoa against cold chock but the precise mechanism by which egg yolk acts is unknown.

It has been proposed that the low-density fraction of yolk, mainly composed of low-density lipoproteins (LDL) from yolk, could be responsible for the resistance against cold shock and for the improvement of motility of spermatozoa after storage.

Phospholipids form yolk could serve as encapsulation systems (liposomes, double emulsions) and proteins from albumen as microspheres and microcapsules to entrap hydrophobic (liposomes, microcapsules) or hydrophilic (microspheres) compounds. More precisely, in human and in animal nutrition, liposomes could be used to increase bioavailability of hydrophobic vitamins like vitamin E. The functionality of such liposomes has been tested in rats, considered as a good model form human digestion/absorption processes. (Cansell *et al.*, 2003).

2.6.3 Cosmetic Industry

Albumen (egg white) has long been used as a facial. Egg yolks are used in shampoos and conditioners and, sometimes, soaps. Cholesterol, lecithin and some of the egg's fatty acids are used in skin care products, such as revitalizes, make-up foundations and even lipstick (American Egg Board, 2017). The protein from egg membranes adheres to and grows human skin fibroblasts and increases their production of type III collagen which is rich in the skin of infants, presumably softening the skin. This egg membrane protein is being used as an ingredient in many cosmetics. Embryo therapy is one of the cosmetic uses of egg; it is an addition to vitamin therapy. When used in cosmetics, the 'stimulating' and 'proliferating' properties of embryo extract were said to help heal and rejuvenate skin, induce elasticity, reduce wrinkles, elevate muscle tone and even reduce swelling around the eyes.

Abdullahi (2016) reported that Chicken embryo extract was used in face creams, serums and face masks, presumably in very small quantities. In many cases it was combined with other biological

like vitamins, placental extract, horse serum, shark liver extract or royal jelly. Serum albumin is supplemented to many wrinkle-reducing cosmetics. Rather than being used alone they are now generally combined with other wrinkle-reducing ingredients including hydrating agents to plump up the skin, fillers to fill in the cracks, and optical masks which disperse light and add a softening effect.

2.6.4. Industrial Uses

The importance of new biodegradable biomaterials is not only that they help to reduce waste materials but they could help to preserve petroleum reserves by substituting synthetic polymers (De Graaf and Kolster, 1998). A plasticizer is often required to overcome film brittleness and helping to avoid chipping and cracking of films during subsequent handling and storage. Plasticizers are molecules with low molecular weight, low volatility, which modify the three-dimensional structure of proteins. Proteins coming from egg albumen could be excellent candidates to obtain a biodegradable plastic material with suitable mechanical properties to be a potential substitute of synthetic polymers in certain applications. (Jerez *et al.*, 2005.)

2.7 Effect of Heat on Eggs

Among several other factors, temperature and pasteurisation are known factors influencing the formation and stability of egg white foam (Hammershoj *et al.*, 2001). Heat can damage the product if contact with high temperature drying air is long, denaturing the egg yolk lipoproteins, a problem that has logically been related to poorer emulsifying properties (Moros *et al.*, 2002; IgnÁrio and Lannes, 2007). Microbiological risks are always there for egg-based food products since eggs might contain salmonella and other sporulated microorganisms. Under the conditions of heat treatment proteins of egg usually lose their many functional properties, particularly their ability of gelling, which only can eliminate such salmonella and spores. The main problem is to

eliminate microorganisms like salmonella and other bacteria during manufacturing dried-egg products, this elimination requires heat application at high temperatures during pasteurization step to the egg mixture, but such high-temperatures application causes coagulation of the egg. While the process of coagulation is irreversible, once the egg agglomerates the egg product has lost its ability of thickening for other food products. (Marcelo *et al.*, 2013)

2.8 Safety Concerns of Egg Use

Several authors have reported that, although the contents of freshly laid shell eggs are generally sterile, microorganisms, some of which are health hazards, can penetrate the shell and multiply under poor holding conditions. Investigations found *pseudomonas* and *coliforms* on peripheries of egg processing equipments. For maintaining quality of egg, proper handling and storage are important. Keeping eggs at room temperature or above 68^0F may cause more quality loss in a day than in a week under refrigeration (Chen *et al.*, 2009). Egg consumption has also been limited by health concerns.

According to Food Policy and Programs (2013), Eggs are either cooked or added to foods that need to be cooked such as cakes, quiches and frittatas. Harmful bacteria are killed by cooking in turn, minimising the risk of them being present in the final meal served. There can be a high risk of harmful bacteria contamination and illness in customers if eggs are added to a food that will not be cooked or are only partially cooked.

2.8.1 Salmonella

The pathogens of chief concern are the numerous microorganisms belonging to the genus Salmonella. If ingested in sufficient number, these microorganisms can cause illness. Our environment is full microorganisms and they found everywhere - in air, animals, soil, water and insects. Foods coming into contact with manure and dirt like eggs and the other produce grown

with manure as a fertilizer have large number of microbes. So it is almost impossible to destroy all microorganisms, but precautions can be adopted to control the occurrence of harmful and dangerous microorganisms (Beuchat and Mann, 2015).

Some consumers do not eat eggs for the fear of food borne pathogens such *Salmonella* (Luber, 2009) and also diseases like avian influenza (Hsu *et al.*, 2008). It is widely known through research that eggs have a high risk of *Salmonella* and they have been a habitat of this pathogen from ancient times. As much as this is true, the message has been wrongly sent to the consumers to such an extent that the nutritional value of eggs has been overtaken by health risk concerns (Mnyandu, 2014).

Salmonella enteritidis has adapted itself to have survival in the hen's reproductive tract, in recent years. So occurrence of *Salmonella enteritidis* on some eggs shell is therefore not unexpected. An egg's inside was once supposed almost sterile but *Salmonella enteritidis* has been revealed inside a little number of eggs, in recent years. Surface cracks of egg shell could however enhance the chances of the microorganism inside the egg. Perishable foods such as fish, eggs, meat, milk and products of milk are highly susceptible to the growth of microorganism (Northcutt *et al.*, 2004).

It has been known that the products made from egg might have some members of the *Salmonella* group which can cause food poisoning, after the recent discovery of *S. paratyphoid* B in the egg product samples imported from UK the problem became more serious and alarming (Chen *et al.*, 2009). These salmonellae before freezing or drying are destroyed through the process of pasteurization. This process is successful and requires careful control conditions. In present scenario the trend of pasteurization process to frozen whole egg in UK is negligible. The size of

the tins in which the frozen product is to be delivered must be up to 20 kg which is suitable for γ-radiation treatment. A range of 0·3–0·5 Mrad of γ-radiation will destroy salmonellae and cure the product quality (Carolina *et al.*, 2014).

2.8.2 Escherichia coli

Escherichia coli fondly referred to as E. coli is a food borne disease and associated with eggs (Food Technology and Processing, 2016). A few of the E. Coli strains found mostly in feces are in themselves pathogenic, causing infection and disease. These are called Enteropathogenic E. *coli* or EEC. Enteropathogenic *Escherichia coli* infection-*Escherichia coli* serotypes are associated with infant and adult infections. Usually, it takes about 10 to 12 hours to manifest its symptoms which can range between 5 to 48 hours. It is characteristered by symptoms such as Headache, malaise, fever, chills, diarrhea, vomiting, abdominal pain. E. coli infection can last for a few days in the body infected.

2.8.3 Regulations Concerning Microbiological Safety of Foods

An extract from Mnyandu, (2014) on Regulations governing microbiological standard for foodstuff and related matters with focus on eggs and egg products are shown below:

1. No person shall sell cooked poultry-

(a) Which contains the followings:

(i) antibiotics and other antimicrobia substances in amount that exceed the maximum levels determined in the regulations governing maximum limits for veterinary medicine and stock remedy residues that may be present in food stuff, published by government notice no. R. 1809 of 3rd July, 1992:

(ii) Organisms of the genera *Salmonella, Shigella* and *Eschericia coli* in 20grams

(iii) *Staphylococcu*s in 20grams;

(iv) *Clostridiumper fringens* in 20grams; and

(b) Of which the total colony counts of organisms exceeds 10000 per gram when such food stuff is tested pour-plate method on plate-count agar at 30°C for 72hours.

2. An egg products after pasteurization or irradiation shall comply with the following microbiological specifications:

(a) *Salmonella* shall be absent in 25ml or grams of an egg product;

(b) *Staphylococcus aureus* shall be absent in 1ml or gram of an egg product;

(c) Mesophillic aerobic bacteria shall not exceed 20,000 colony forming unit per gram or millilitre;

(d) Coliforms shall not exceed 50 per gram or milliliter of an egg product; and

(e) Yeast and molds shall not exceed 200per gram or millilitre of an egg product.

2.9 Processing Methods of Egg Powder

Processing of eggs into powders ensures that during storage the final powders reveal better stability and flowability and less formation of cake by retaining dissolution times and good rehydration (Asghar *et al.,* 2012). Irrespective of the method adopted, it has a potential for longer shelf life Dodrill (2014). Methods of egg processing are varied.

2.9.1 Dehydration

Drying and dehydration are one of the oldest and popular methods for preservation purposes and the terms are often used alternatively without much of a difference though they are not the same according to US Department of Agriculture. Dehydrated food cannot have moisture contents above 2.5% on dry basis while dried food can have moisture content above 2.5% (dry basis). Most important characteristic specifications of products include a longer shelf life, a fresh appearance, convenience tastiness, crunchiness, healthiness and, of course, a lower price. In the

baking industry, ingredients work in collaboration to obtain the desired texture and structure of bakery products (Abdullah, 2008).

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 and freeze drying (Vega-Mercado *et al.*, 2001).

Simultaneous heat and mass transfer takes place during dehydration and drying processes, this causes changes in the dried product. In cake production, eggs perform different kinds of functions, providing volume to the product, tenderness, structure and some nutritional qualities to the product. They have high protein contents and can have ability to form firm and complex networks with gluten due to their binding ability. Due to their whipping property and forming stable foams, they participate in the development of cake structure and volume. The egg proteins are denatured upon heating, in this way they help in stabilizing and setting the structure of product crumb. The yolk portion of an egg contains high lecithin and lipid contents which impart a tenderizing and emulsifying effect to the product. Eggs help in stabilizing the emulsion, retaining gas produced by the leaveners and preventing coalescence of air cell in the batter, resulting in desirable texture and fine crumb grain. Eggs also give little but significant color and flavor (from the yolk portion) and enrich nutritional value of cake (DesRochers *et al.*, 2003). Dehydration of eggs has been reported commercially and in home kitchens to be a very easy process. A typical practice involves cracking a dozen eggs and pouring the mix into a blender to thoroughly mix. Dehydration is usually done for 12 hours at 135-140 degrees. Powdering of the eggs is done using a food processor or blender so as to maximize storage space. One tablespoon of egg is mixed with two tablespoons of water and stayed for five minutes for them to rehydrate and used as scrambled or in baking just as fresh eggs are used (Erich, 2016).

2.9.1.1 Merits and Demerits of Dehydrated Food

Dehydrators have been reported to function well and allows for the making of dehydrated eggs, cottage cheese, sour cream, jerky and countless fruits and vegetables. Slicing or spreading the food items to be dehydrated is important to reducing the amount of energy used during the process. Also, solar dehydrators for outdoor use are both commercially available and can be made fairly simply at home as well. Dehydrated foods offers not only a cost savings but the peace of mind of knowing exactly what the consumer aims at serving the consumers for the coming food riots (i.e. in time of food scarcity). Multitudes of free recipes exist online that include dehydrated food items, and long shelf life baking products that can be placed inside a Mason jar for quick and easy snacks and meals several years into the future (Dodrill, 2017).

2.9.2 Freeze drying method

Freeze drying makes it possible to prolong the life leafy greens while simultaneously turning them into delicious snack food. Very few foods provide the nutrition that's contained in one egg piece. Freeze drying makes it possible to preserve nutrients and proteins in a far less fragile state. They are produced from pasteurized liquid egg products by using a blast freezer at temperatures of –10°F to –40°F.Frozen egg products have a long shelf life when kept at less than 10°F.Cooked or raw scrambled eggs are a perfect fit for freeze drying. Raw eggs can be whisked, freeze dried and kept in their powdered form to use in all baking and cooking recipes. Eggs can also be freeze dried in their scrambled state and easily re-hydrated to reconstitute for further use. Often times, freeze dried foods are preferred over dehydrated food, but both varieties have advantages and disadvantages. Water and time are needed for both types of long-term storage food (Abdullahi, 2016; Dodrill, 2017).

2.9.2.1 Merits and Demerits of Freeze Dried Food

Freeze dried food is flash frozen and then placed inside a vacuum pouch or container. Unlike the long dehydrating process, water in freeze dried food vanishes quickly. The fast removal of moisture prevents the food from shriveling or looking "deformed" as it can often do during the dehydration process. Typically, freeze dried food rehydrates more quickly than dehydrated food. If time is of the essence or fuel is in short supply during an emergency situation, the minutes and energy saved by using freeze dried food could be a significant factor to consider when deciding long-term food storage. With a freeze dryer, old eggs will not be thrown out again, and this, will also take care of impromptu brunch or get-together with blueberry muffins, waffles or a soufflé. (Dodrill, 2014).

2.9.3 Spray drying method

Spray-drying technology is used in an extensive variety of processes ranging from manufacturing of food products to pharmaceuticals. Spray-drying technology is applied extensively in several industries like in the food industry; for instance, drying of a feed solution for generating specific products from the solution (Verdumren *et al.*, 2001; Oakley, 2004). Spray-drying process also has been utilized to manufacture solid or hollow micro-particles for various applications like composites of lightweight (Wilcox and Berg, 1994; Shabde *et al.*, 2005). The design criterion of primary spray-drying chamber is the moisture content of the resulted particle. The prediction of the resulted properties of particle is compared to the data of experiment taken from a laboratory unit of spray-drying. The final results showed that the design of final spray-drying chamber is affected by the flow rate of liquid feed, the temperature of inlet drying gas, and loss of heat (Shabde and Hoo, 2006).

Buchi, (2006) carried out an experiment using a laboratory scale system and reported that a small device such as the B-190 Mini Spray Dryer is particularly interesting to produce small volumes of product within a short time. The device could handle spray drying processes in 50 mL batch volumes and up to 1 L of solution per hour and with its glassware, complete drying process is achieved from the two fluid nozzles down to the collection vessel visible. Hence, the product parameters resulting from the drying method were affected by the instrument settings, and are therefore usually optimized through trial and error.

2.9.3.1 Merits and Demerits of Spray dried eggs

Spray drying allows preparation of stable and functional powder products (Sagar and Kumar, 2010) and can be implemented for large scale through puts (Youssefi *et al.*, 2009).

Liquid egg is converted to powdered products by spray drying process. The properties of eggs are very delicate and the final quality of the dried product can be affected by drying condition (Bequest 1980) for egg powder production most of the research and literatures were related with the method spray drying (Caboni *et al.*, 2005).

2.10 Functional properties of Eggs and Egg powder

Functional properties refer to the chemical and physical attributes of both liquid and dried egg powder that makes it suitable in the application and use for food materials as ingredients for the production of various food products. Functional properties of eggs include emulsifying activity, foaming capacity, stability, water activity, oil absorption, bulk density.

Pearce *et al.* (1978) defined the following functional properties and highlighted their importance as follows: Emulsifying activity is the ability for a surfactant to form an emulsion under given condition and is directly related to oil droplet size hence the smaller the size the greater the

activity. By nature, emulsions are thermodynamically unstable and eventually separate into oil and water phases, therefore it is the measure of how slowly an emulsion separates into oil and water phases. The emulsification properties of food materials are necessary for the stability of the suspension of one liquid in another. Foaming capacity and stability indicate swelling capacity which is of importance in the bakery industry. Water activity and oil absorption properties of eggs help to retain moisture and oil during baking and subsequent storage. It enhances both the physical and sensory qualities of their products. Bulk density is an important property of powder foods, granules and other solid and helps indicate the total volume they can occupy. Generally, higher bulk density is desirable for greater ease of dispensability and reduction of paste thickness.

Functional properties of whole egg powder as cited by some authors are indicated in Table 2.3.

Table 2.3: Functional Properties of Oven dried Whole Egg powder

	Whole egg powder	
Functional properties	**1**	**2**
Emulsification capacity (%)	55.00	74.34
Foaming capacity (%)	40.00	57.23
Foaming stability (%)	59.29	76.30
Water absorption capacity (g)	1.60	57.23
Oil absorption capacity (g)	2.60	3.06
Water Retention (g)	-	2.92
Oil Retention (g)	-	4.08
Swelling Capacity (%)	-	2.07
Bulk density (g/ml)	-	5.43

Source: [1]Ndife *et al.* (2010)

[2]Abdullahi (2016)

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 a cohesive visco-elastic film by way of intermolecular interactions (Mine, 1995). During beating, increase in volume is attributed to the egg viscosity, whereas the volume increase in the oven is due to egg proteins coagulation. While the protein's elastic properties are lost during cooking of eggs, the protein's firming properties allow eggs to perform other functions. As their proteins agglomerate, egg ingredients bind together. Crumbling of meat loaves is less likely and casseroles serve in smaller portions. Crumb coating to a veal cutlet holds more tightly before being rolled in breadcrumbs when it's been dipped in egg. In quiche and crème caramel, proteins of egg unwind and bond to form a mesh like structure that traps cream and milk in a soft gel. While in a crème anglaise or stirred custard, eggs thicken in consistency just as efficiently, but this happen at lower temperatures than corn-starch and flour. Lecithin and some other emulsifiers in yolks of egg come in handy too. Suspension of small fat droplets occurs throughout the emulsions when coated with a thin film of yolk like in hollandaise, mayonnaise and béarnaise emulsions (Hammershoj *et al.,* 2001). Several studies have reported and identified steps involved in processing which are responsible for damaging the functional properties of egg albumin, and to evaluate the techniques and processes that could be performed in order to minimize these effects and to mitigate time of dry-heating.

These distinctive sauces wouldn't be as important, luxurious and as smooth without the egg's emulsifying properties. Egg whites and egg yolks play various functions in making of cake and slight changes in the amount of egg whites and egg yolks will influence the baked cake. Yolk will produce more flavourable and darker coloured cake but having less structure. Egg whites

form a cake softer in texture because egg albumins don't have as much firming properties as egg yolks have (Abdullahi, 2016).

2.11 Organoleptic Properties of Cakes

Cakes are predominantly popular and connected in the mind of consumer with a delectable product with significant characteristics of organoleptic. The most important ingredients used in cake making are sugar, egg, fat and flour and each plays an excellent purposeful role in the eating and structural quality of the food product (Conforti, 2006). More particularly, a cake batter reveals a complicated foam and emulsion system which is processed by being heat set systems. Cake baking leads to an aerated and light structured product, as well as a large amount of volatile compound formation, which plays a significant role in formation of its characteristic flavor. These compounds are basically the final product of the maillard reaction, which takes place between the amino group of amino acids and reducing sugars, proteins and peptides **(**Asghar *et al.*, 2012).

The raw material selection, as well as modification of the making method can change composition of cake structure and aroma. Pozo-Bayo *et al.* (2007) suggested that by changing the formula of a cake and by replacing eggs with a leavening agent, significant modifications in some basic aroma compounds were observed, while Paraskevopoulou and Kiosseoglou (1997) reported that cakes formed from low cholesterol egg yolk concentrates had stiffer and harder textures compared to others.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental sites

The study sites were the Central Laboratory Complex of Bayero State University Kano (BUK) located approximately 12.8 kilometers (7.95 miles) from the city along Kano-Gwarzo Road, Kano State, Nigeria (BUK, 2017); Vetco diagnostic laboratory, Kaduna; Biochemical Laboratory and Animal Products Laboratory, Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University, Samaru, Zaria, Nigeria, located between latitude 11°9'46"N and Longitude 7°37'45''E at an altitude of 610 meters above sea level (Institute for Agricultural Research Meteorological Unit, 2016).

3.2 Experiment One: Production and Evaluation of Differently Processed Whole Egg Powders

3.2.1 Egg Powder Production

Two processing methods (Freeze dried and Dehydrator) were employed in making the whole egg powder from fresh eggs at the Bayero University Central Laboratory, Kano and Biochemistry Laboratory, Ahmadu Bello University, Zaria respectively.

The Freeze Drying method entailed using thirty five (35) pieces of commercial layers egg obtained from National Agricultural Extension and Research Liaison Services (NAERLS) farm. They were neatly unshelled and whisked thoroughly with the aid of a Sonik Japan Model, SB-1515 blender to ensure albumen-yolk homogenization, then the mixture was placed in a SB4L Freeze dryer set at -40°c and left to dry for 48 hours. After 18 hours of drying, the eggs were stirred randomly to ensure uniform drying and to prevent molding together. After drying, the eggs which appeared in a dried-crumbled form were blended with a dry blender set at 'max' for

30 seconds to get the egg powder product. The whole egg powder was packed and stored in Ziploc bags of 3 X 6" dimension for further evaluation.

Another 35 egg pieces obtained from NAERLS farm were used for the Dehydrator method. The eggs were unshelled and whipped up with the aid of a blender to enhance homogeneity, thereafter the egg slurry was poured into a fruit-roll sheet (a tiny non-stick layer attached to the dehydrator) and then the temperature of the dehydrator (PRESTO Dehydro digital electricfood dehydrator 06301) was set at 145^{o}F (62.8^{o}C). The whole egg slurry was allowed to dry for 19 hours until they were completely in brittle form. The dried brittle egg was packed and poured into a dry blender set at 'max' for 30 seconds and blended into powder. The whole egg powder was stored as above.

3.2.2 Proximate Composition Analysis:

The Commercial, Freeze and Dehydrator dried whole egg powder samples were analysed for proximate composition according to AOAC (2000) procedure.

3.2.2.1 Dry matter (DM)

Moisture content determination was carried out using the air oven method. Crucibles were washed and dried in an oven. They were allowed to cool in the desiccator and the weight was noted. The samples were dried at temperature 60^{o}C for 3 days. The dried samples were cooled in a desiccator and weighed. They were later returned to oven and the process continued until constant weights were obtained.

$$DM = \frac{\text{Weight of sample before drying (g)} - \text{Weight of sample after drying (g)}}{\text{Weight of sample before drying}} \times 100$$

3.2.2.2 Crude Protein (CP)

The crude protein content was determined using micro Kjeldahl method as described (AOAC, 2000). 0.5g of sample was weighed into a long necked Kjeldahl flask. One (1) tablet of Kjeldahlcatalyst was added to the sample in the flask with 25$cm^3$of concentrated H_2SO_4. The flask was swirled, gently clamped in an inclined position and heated in a fume cupboard. The heating continued until a clear solution was obtained. The clear solution was cooled, then poured into a 100cm^3 volumetric flask and made up to mark with the distilled water. 10 ml of the resulting mixture was measured into the distillation set through the funnel. 5cm^3 of boric acid was pipette into a 100cm^3 conical flask and placed at the receiving end of the distillatory.

The conical flask was placed such that the delivery tube dipped completely into the boric acid inside the flask. 40% NaOH was used to liberate ammonia out of the digest under alkaline condition. During the distillation, 2 drops of methyl orange were added to the round bottom flask containing the digested sample before 40% NaOH was added. As soon as the content became alkaline, the red colour changed to yellow showing NaOH to be in excess. Steam was then generated into the distillation set using a steam chest. The liberated ammonia was trapped in the boric acid solution and about 50cm^3 if the solution was collected into the conical flask. The solution in the flask was titrated against 0.1M HCL until the first permanent colour change was observed. A blank sample was used in the sample procedure and the titre value for the blank was used to correct the tire for the sample.

$$\%N = \frac{0.01 \times 0.014 \times t \,(250/\,5 \times 100)}{\text{Weight of sample (g)}}$$

0.01 = molarity of HCL 0.014 = mole equivalent of nitrogen

t = titre value of HCL N = nitrogen sample

*The determination of nitrogen allows the calculation of the protein content of the sample. The crude protein content was determined by multiplying percentage nitrogen by a constant factor of 6.25(since the average protein contains 16% nitrogen).

3.2.2.3 Ash Value

1g of dried samples was weighed into clean, dried preciously weighed crucibles. The samples were ignited over a low flame to char the organic matter using and electro thermal heat. The crucibles were then placed in muffle furnace at 600^{o}C for hours until it ashed completely. The ashed samples were then transferred directly to desiccator, cooled and weighed immediately.

$$\% \text{ ash} = \frac{\text{Initial weight (g)} - \text{ash weight (g)}}{\text{Initial weight (g)}} 100$$

3.2.2.4. Ether Extract (crude fat)

The soxhlets extraction method was used. 1g of sample was weighed into a weighed filter paper and folded neatly and then placed inside pre-weighed thimble. The thimble was inserted into the Soxhlets apparatus and extraction under efflux was carried out with petroleum ether (40^{o}C-60^{o}C) boiling range for 7 hours. At the end of extraction, the thimble was dried in the oven for about 30minutes at 100^{o}C to evaporate off the solvent and thimble was cooled in a desiccator and later weighed.

The fat extracted from a given quantity of sample was then calculated:

$$\% \text{ Fat} = \frac{\text{Initial weight of sample (g)} - \text{final weight of sample (g)} \times 100}{\text{Original weight of sample (g)}}$$

3.2.2.5 Nitrogen Free Extract (NFE)

The percentage Nitrogen Free Extract was calculated from subtracting the obtained percentage crude protein, ash, moisture and ether extract from 100

%NFE = 100 – (% crude protein + %ash + % moisture + ether extract)

3.3 Microbial-count Analyses

Preparation of media: Plate Count Agar and McConkey agar media were utilized for total bacteria count, coliform count and non-coliform count. Sabauroud dextrose agar media was used for isolation of fungal organisms after incubation for 2-3 days at room temperature and triple sugar ions agar for selective isolation and identification of *Salmonella* spp. All the media were prepared following the manufacturer's instruction and sterilized by autoclaving at 121ºC for 20 minutes following the method described by Osei-Somuah *et al.* (2003).

Sterile opening and egg mixing for culture: The surface of each of the eggs was disinfected with 70% ethanol in order to culture the content of eggs. For each of the egg samples, a sterile spatula was used to create an opening in the egg and the content was poured into a sterile measuring glass beaker then thoroughly mixed.

3.3.1 Total bacteria, Coliform and Non-coliform:

Total bacteria, coliform and non-coliform counts, were determined by the spread plate method as reported by Bartram *et al.* (1996). Plates showing colonies were selected, counted and the results were presented in CFU/ml for raw eggs and CFU/g for egg powder.

3.3.2 Culture of fungi:

Fungi were identified by colonial and cellular morphology using lacto-phenol cotton blue staining technique. Biochemically, tests such as citrate utilization, methyl red, urease test were carried out (Holt, 1994).

3.3.3 Selective isolation of Salmonella spp:

A sterile inoculating wire loop was used to pick a colony from the non-coliform growth on the McConkey medium and sub-culture it on the triple sugar Ions agar in a slant tube. The inoculated

medium was then incubated for 24 hours at 37ºC. This procedure was repeated for all the samples.

3.4 Functional Properties

Samples of the whole egg powder obtained from the two processing methods above were subjected to functional analysis and the following parameters were analyzed.

3.4.1 Emulsifying Activity

The emulsion (1g egg powder, 10ml distilled water, 10ml soybean oil) was inserted in a calibrated centrifuge tube (100ml). The emulsion was centrifuged at 2000rpm for 5 minutes. The ratio of the height of the emulsion layer to the height of the mixture was calculated as the emulsion activity expressed in percentage following the methods outlined by Yasumatsu *et al.* (1972).

$$\text{Emulsifying Activity} = \frac{\text{Height of the emulsified layer}}{\text{Height of the total amount of content in the tube}} \times 100$$

3.4.2 Swelling Capacity

Swelling capacity was established according to the method of Coffman and Garcia (1997). One gram of dried egg powder was weighed into a 100ml conical flask and 15ml distilled water was added. The mixture was shaken for 15 minutes at low speed on a stirrer and transferred into a hot water bath and heated for 40 minutes between 80-85°C with constant stirring. The heated mixture was transferred to a pre-weighed centrifuge tube and 7.5 mil distilled water added and centrifuged at 2200rpm for 20 minutes. The supernatant was carefully decanted and cooled in a desiccator. The precipitate with the centrifuge tube was weighed.

$$\text{Swelling capacity} = \frac{\text{Weight of the centrifuge containing sample before drying}}{\text{Weight of the centrifuge containing sample after drying}} \times 100$$

3.4.3 Foaming Stability/ Foaming Capacity

Foaming stability was estimated after the foaming capacity has been established. To calculate foaming capacity, two (2) grams of egg powder was whipped (homogenised) with 100ml distilled water for 5minutes in a SONIK JAPAN MODEL, SB-1515 blender at speed setting 'max' and then poured into a 250ml graduated measuring cylinder. The total volume at 15mins was noted. Percent volume increase was calculated as established by Coffman and Garcia (1997).

$$\text{Foaming capacity} = \frac{(\text{Volume after whipping} - \text{Volume before whipping})\ \text{ml} \times 100}{(\text{Volume before whipping})\ \text{ml}}$$

$$\text{Foaming stability} = \frac{(\text{Volume after standing} - \text{Volume before standing})\ \text{ml} \times 100}{(\text{Volume before standing})\ \text{ml}}$$

3.4.4 Bulk Density

This was determined according to Narayana and Narasinga (1984) methods. Ten grams of each samples (egg powder) was weighed (W1) into a 25ml graduated measuring cylinder. The sample was gently tapped to eliminate space between the powder samples and reweighed (W2). This process was conducted in triplicate.

Bulk density (g/ml) = W1 - W2

Volume of sample before tapping

Where, W1 = weight of sample before tapping, W2 = weight of sample after tapping.

3.4.5 Water and Oil Absorption Capacity (WAC/OAC)

Water and oil absorption was determined using the method described by Sefa-Dedeh *et al.* (2004). Five grams of the powdered egg was weighed into a centrifuge tube and 20ml of distilled water was added. The mixture was stirred and allowed standing for 30 minutes and centrifuged at 3000 rpm for 15minutes. The supernatant was decanted, noting the increase in weight by

weighing with a digital balance. The water and oil absorption capacity was expressed as a percentage of the initial sample weight. The determination was done in triplicates.

$$\text{WAC} = \frac{\text{Hydrated residue weight} - \text{Dry residue weight}}{\text{Dry residue weight}}$$

$$\text{OAC} = \frac{\text{Hydrated residue weight} - \text{Dry residue weight}}{\text{Dry residue weight}}$$

3.4.6 Water and Oil Retention Capacity (WRC/ORC)

One gram of the powdered egg was mixed with 10 ml refined soybean oil and centrifuged for 10 minutes at 2000rpm. Water and oil retention was expressed as percent water and oil bound per gram of the sample according to the Sosulski *et al.* (1976) procedure.

$$\text{WRC} = \frac{\text{Residue hydrated weight after centrifugation} - \text{Residue dry weight}}{\text{Residue dry weight}}$$

$$\text{ORC} = \frac{\text{Residue hydrated weight after centrifugation} - \text{Residue dry weight}}{\text{Residue dry weight}}$$

3.5 Sensory Analysis

Two major whole egg products namely scrambled egg (un-spiced) and cake were used to assess the quality of the whole egg powder samples. The consumer panel composed of thirty (30) single members with age range of 23-26years who are majorly students, seated apart to minimize interaction in well illuminated laboratory. Clean water, liquid detergent and serviette for hand cleaning were provided to the entire panelists prior to the evaluation process. A sachet of water for mouth-rinsing after tasting each sample was also provided.

An organoleptic assessment was done using a 9-hedonic scale score sheet that was given to each panelist to record their perception and observation. The processed un-spiced scrambled egg and cake samples were labeled with codes only known to the researcher and served in a covered petri-dish.

3.5.1 Preparation of Un-Spiced scrambled egg

Egg powder samples obtained from the three sources (commercial, freeze dried and dehydrated) were reconstituted with water following the method described by Ross (2008). Twelve table spoons of egg powder were mixed with 24 table spoons of water giving a reconstitution ratio of 1:2 of egg and water respectively. Reconstituted eggs of the three whole egg samples were individually fried as unspiced scrambled (without spice or seasonings) and were subjected to uniform specifications such as quantities of vegetable oil, time of frying. Ten table spoons (50ml) of vegetable oil was used for all the slurry and fried for five minutes each using a gas burner. The scrambled eggs were served in petri dishes to the panelists and a 9-point hedonic scale sheet given for product assessment.

3.5.2 Production of Cake

Cakes were made using the reconstituted powders and other standard ingredients used in baking. Uniformity across the preparatory process was ensured for the three whole egg powder samples. After cooling, the cakes were cut in a square shape of 2cm X 2cm and served to the panelists to evaluate as explained for un-spiced fried eggs above.

3.6 Experiment Two: Effect of Egg Storage Period on Whole Egg Powder Quality

The dehydrator method was used in determining the effect of egg age on the quality of the egg powder produced. Two trays (60 pieces) of freshly laid eggs were obtained from National Agricultural Extension Research and Liaison Services (NAERLS) research farm in bulk, washed with warm clean water to remove poultry debris and were divided into four treatment groups, each containing fifteen pieces. The first group (Treatment 1) was subjected to the drying process on the day of collection and recorded as Day 0, following the same procedure used in experiment one. Groups two (Treatment 2), three (Treatment 3) and four (Treatment 4) were stored in a cool

dry place at an average room and surface temperature of 27^{o}C and 28.45^{o}C respectively obtained using a Rycom Non-contact Infrared Thermometer (Model: JXB-181) and subjected to the drying process on days 7, 14 and 21 respectively. The powders obtained from the four groups were subjected to proximate analysis, microbiological analysis and functional analysis.

3.7 Statistical Analysis

Data obtained were analyzed using ONE-WAY ANOVA statistical model. Means and mean differences were separated using Duncan's multiple range tests, SAS 9.0 (SAS 1993).

3.7.1 Model

The model used was:

Yij = μ + Ti + Eij

Yij = Overall mean/ Observation record

μ = Population mean

Ti = Treatment

Eij = Random error

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Product Yield

The yield of egg powder per egg obtained from the freeze, dehydator and spraying drying processing methods amounted to 4.33ml/g, 4.47ml/g and 4.62ml/g respectively which translated to 23.1%, 22.4% and 26.7% for the various processes respectively. Approximately, 1 egg gave 12g, 12.7g and 12.3g of whole egg powder for FDWEP, DDWEP and SDWEP respectively. These results are shown in Table 4.1. Generally, the effects of freeze drier, dehydrator and spray drying (method adopted for the commercial egg powder) products are characterized by the reduction in the initial quantities of the liquid and higher quality concentration in such products. From the yield results, the spray drier rate of drying whole egg liquid was more effective than dehydrator and freeze drier which showed their quality inversely. The egg powder yield compares favorably with the yield percentage result of (21.90%) oven dried chicken eggs reported by Abdullahi (2016).

4.2 Proximate Composition of Egg Powders

The proximate composition of differently processed and commercial whole egg powders are outlined in Table 4.2. There were significant differences ($P<0.05$) across the treatments for dry matter, crude protein and nitrogen free extract. The significantly higher dry matter value (95.00%) recorded for the Spray Dried Whole Egg Powder (SDWEP) is a reflection of the higher efficiency of the spray dryer in drying the liquid egg as against the other methods. The higher crude protein value also recorded for the SDWEP is probably a consequence of the higher retention of nutritional properties especially the protein found in spray drying of food materials. Ether extract and Ash contents across the treatments had no significant differences with Freeze

Table 4.1: Yield in ml/g, g and % of differently processed egg powder

Yield	ml/g	G	%
FDWEP	4.33	12	23.1
DDWEP	4.47	12.7	22.4
SDWEP	4.62	12.3	26.7

FDWEP- Freeze dried whole egg powder
DDWEP- Dehydrator dried whole egg powder
SDWEP- Spray dried whole egg powder
ml/g- mills per gram, g- grams, %- percentage

Table 4.2: Proximate composition of differently processed whole-egg powders

Nutrients	FDWEP	DDWEP	SDWEP	SEM
Dry matter	92.28[c]	93.93[b]	95.00[a]	0.25
Crude protein	49.92[b]	50.71[b]	52.78[a]	0.50
Ether extract	3.77	3.37	3.02	0.39
Ash	1.96	1.92	1.84	0.08
Nitrogen free extract	44.36[a]	44.38[a]	42.37[b]	0.42

[abc]Means with different superscripts within rows differ significantly, SEM= Standard error of mean, FDWEP= Freeze dried whole egg powder, DDWEP= Dehydrator dried whole egg powder, SDWEP = Spray dried whole egg powder.

Dried Whole Egg Powder (FDWEP) having (3.77, 1.96), DDWEP (3.37, 1.92) and SDWEP (3.02, 1.84) respectively. Crude protein and Nitrogen free extract results of the two processed powders (FDWEP, DDWEP) had similar results. These results values were similar to ranges obtained by Mine (2007) and Woo and Bhandri (2013).

4.3. Microbial load of Egg Powders

Table 4.3 shows the microbiological load of differently processed whole-egg powders. There were no significant differences ($P>0.05$) across the treatments for total coliform count, non-coliform count, total bacterial count and yeast count. Significant ($P<0.05$) differences however occurred for mold count across treatments with FDWEP having the highest (0.330CFU) and differing from the other treatments. Salmonella was negative across the powder treatments and positive for raw egg while *E.coli* was negative across all the treatments. This result agrees with Gibbons *et al.* (2011) who stated that over 99% of the *Salmonella* organisms in liquid egg were killed on drying in an experimental spray dryer. The significant mould count recorded in the FDWEP group could be as a result of its higher moisture content.

4.4 Functional Properties of Egg Powders

The functional properties of differently processed and commercial whole-egg powders as well as raw egg are shown in Table 4.4. There were significant differences ($P<0.05$) across the treatments for all parameters evaluated except bulk density.

Foaming capacity had the highest value in FDWEP but did not differ significantly from raw eggs and SDWEP (31.64, 31.43 and 30.06% respectively). Highest ($P<0.05$) foaming stability and emulsifying capacity values were recorded among raw, DDWEP and SDWEP treatments. This implies that the functionality of all the whole egg powder is generally lower than the raw whole

Table 4.3: Microbial load of differently processed whole-egg powders

Parameters	FDWEP	DDWEP	SDWEP	SEM
Total-coliform count (CFU/ml/g)	0.000	0.000	0.000	0.000
Non-coliform count (CFU/ml/g)	0.042	0.019	0.030	0.540
Total bacteria count (CFU/ml/g)	0.175	0.120	0.136	0.570
Mold count	0.330[b]	0.000[a]	0.000[a]	0.002
Yeast count	-ve	-ve	-ve	
Salmonella spp	-ve	-ve	-ve	
E. coli	-ve	-ve	-ve	

[ab]Means with different superscripts within rows differ significantly($P<0.05$), SEM= Standard error of mean, FDWEP= Freeze dried whole egg powder, DDWEP= Dehydrated dried whole egg powder, SDWEP = Spray dried whole egg powder.

Table 4.4: Functional properties of differently egg processed powders and raw eggs

Parameters	FDWP	DDWEP	SDWEP	RAW EGG	SEM
Emulsifying capacity %	26.04[b]	27.9 [a]	28.13[a]	28.27[a]	0.64
Swelling capacity %	101.77[c]	102.00[b]	102.7[b]	111.16[a]	0.35
Foaming stability %	74.34[b]	86.37[a]	85.10[a]	88.94[a]	2.80
Foaming capacity %	31.64[a]	30.00 [b]	30.06[ab]	31.43[ab]	0.77
Bulk density (g/ml)	0.003	0.003	0.007		0.005
Water Absorption capacity (g)	0.27[c]	0.27[c]	0.30[b]	0.74[a]	0.01
Oil Absorption capacity (g)	0.27[c]	0.27[c]	0.30[b]	0.74[a]	0.01
Water Retention capacity (g)	0.40[a]	0.33[b]	0.31[b]	0.43[a]	0.02
Oil Retention capacity (g)	0.29[b]	0.31[b]	0.28[b]	0.37[a]	0.02

[abc]Means with different superscripts within rows differ significantly($P<0.05$), SEM= Standard error of mean, FDWEP= Freeze dried whole egg powder, DDWEP= Dehydrated dried whole egg powder, SDWEP = Spray dried whole egg powder.

egg powder, but may not have a negative effect on the products in which the egg powder will be incorporated. The values for Water retention capacity were significantly higher in raw eggs and FDWEP (0.43, 0.40g) than DDWEP and SDWEP (0.33, 0.31g). Swelling capacity, water absorption capacity, oil absorption capacity and oil retention capacity had higher ($P<0.05$) values in raw egg. Bulk density was not significantly different ($P>0.05$) in all the egg powder treatments.

The significantly better results observed for most parameters in raw eggs could be adduced to proteins of egg losing their many functional properties under the conditions of heat treatment as cited by Abdulahi (2016).

4. 5 Organoleptic Evaluation of Fried Egg Powders

Table 4.5 expresses the organoleptic evaluation results of fried unspiced raw egg from differently processed whole-egg powders. All determined parameters significantly varied amongst the treatments. The colour of the fried unspiced raw egg was rated best ($P<0.05$) among the treatments with a score of 7.70. The flavor of the raw egg though possessing the highest score of 5.47 did not differ significantly ($P>0.05$) from DDWEP and SDWEP. Texture and taste ratings followed a similar trend with the fried egg from raw, SDWEP and FDWEP not differing significantly ($P>0.05$). Acceptability results were significantly higher in raw eggs and SDWEP (7.30, 5.63) however, the egg powder treatments were not significantly different ($P>0.05$) from one another implying that the "home made" powders compared favourably with the commercial. The preference for the fried raw egg colour could be attributed to the lighter colour of the product after frying as there was a rapid change in the yellow colour of egg slurry immediately after introduction to the cooked frying oil and the panelists seemed to prefer this to the darker

Table 4.5: Organoleptic evaluation of fried unspiced egg of raw eggs and differently processed whole-egg powders

Parameters	FDWEP	DDWEP	SDWEP	RAW EGG	SEM
Colour	4.17[b]	4.70[b]	4.63[b]	7.70[a]	1.01
Flavour	3.00[b]	4.00[ab]	3.97[ab]	5.47[a]	1.16
Texture	4.80[ab]	3.97[b]	5.73[ab]	6.27[a]	1.05
Taste	3.43[ab]	3.33[b]	5.50[a]	6.43[a]	1.04
Acceptability	4.43[b]	4.97[b]	5.63[ab]	7.30[a]	1.13

[abc]Means with different superscripts within rows differ significantly($P<0.05$), SEM= Standard error of mean, FDWEP= Freeze dried whole egg powder, DDWEP= Dehydrated dried whole egg powder, SDWEP = Spray dried whole egg powder.

Table 4.6: Organoleptic evaluation of cakes from differently processed whole-egg powders and raw eggs

Parameters	FDWEP	DDWEP	SDWEP	RAW EGG	SEM
Colour	3.40[b]	4.30[ab]	4.40[ab]	5.50[a]	0.87
Flavour	4.53	4.57	5.17	4.53	1.12
Texture	4.10	4.67	5.17	4.57	1.12
Taste	5.57	6.10	6.63	6.67	1.95
Acceptability	6.17	5.97	6.57	6.30	2.10

[ab]Means with different superscripts within rows differ significantly($P<0.05$), SEM= Standard error of mean, FDWEP= Freeze dried whole egg powder, DDWEP= Dehydrated dried whole egg powder, SDWEP = Spray dried whole egg powder.

yellow colour observed among the egg powder samples. The very yellow colouration of the powders retained in the fried unspiced egg was a bit extreme and less appealing to the panelists which influenced their preference for the lighter coloured raw egg made into scrambled egg.

4.6 Organoleptic Evaluation of Cakes Made from Egg powders

The organoleptic evaluation of cake made from differently processed whole-egg powders as shown in Table 4.6 revealed that only colour differed significantly ($P<0.05$) with raw egg, SDWEP and DDWEP comparing favourably ($P<0.05$). There were however no significant differences ($P>0.05$) between the differently processed egg powders attesting to the acceptability of all of them. This significance may be due to colour-appeal to the panelists as they showed preference for the lighter colour of raw egg samples.

Browning in the cake samples could have been due to Mallard-type reactions (Potter and Hotchkiss, 2006) resulting from the presence of reducing sugars, proteins and amino acids and caramelization due to the effect of severe heating during processing (Mannay and Shadaksharaswany, 2005).

4.7 Effect of Egg Storage period on Whole Raw Egg Proximate Composition

Table 4.7 shows the effect of egg storage period on the proximate composition of whole raw eggs. There were significant differences ($P<0.05$) across the treatments for dry matter, crude protein, lipid, ash and nitrogen free extract with the exception in crude fibre. Dry matter of egg powder from week 3 (54.52) and week 1 (52.45) were significantly ($P<0.05$) highest. The highest values for crude protein were recorded in Week 1 eggs (19.12%) while the lowest values were recorded at week 2 and 4 (16.50). However, there were no significant differences ($P>0.05$) between weeks 2, 3 and 4. Week 2 egg powder had the highest ($P<0.05$) value for lipid and ash (6.03, 3.38%) respectively while the lowest values was recorded in week 3 (2.05%) with no

4.7: Effect of egg storage period on the proximate composition of raw eggs

	Storage period				
Nutrients	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**SEM**
Dry matter	52.45[a]	47.39[b]	54.52[a]	44.53[b]	1.84
Crude protein	19.12[a]	16.50[b]	17.02[b]	16.50[b]	0.78
Lipid/Ether extract	4.20[b]	6.03[a]	4.09 [b]	3.80[b]	0.37
Ash	2.20[bc]	3.38[a]	2.05[c]	2.52[b]	0.19
Nitrogen Free Extract	74.4 [b]	74.09[b]	76.84[a]	77.18[a]	0.86
Crude Fibre	0.00	0.00	0.00	0.00	0.00

[abcd]Means with different superscripts within rows, SEM = Standard error of mean

significant difference (P<0.05) with week 1 powder. NFE had significantly (P<0.05) higher values for weeks 4 and 3 powders (77.18 and 76.84) respectively. Crude fibre of powders had no significant difference as there were no values recorded.

4.8 Effect of Egg Storage period on Whole Raw Egg Microbial load

The effect of egg storage period on the microbial load/counts of raw eggs is shown in Table 4.8. There were significant differences (P<0.05) across the treatments for total bacteria count, total coliform count and non-coliform. The highest values for total bacteria count and non-coliform count were recorded in week 2 (0.780 and 0.49) egg and were significantly different (P<0.05) from all other treatments while the least values were recorded in week 1 (0.304 and 0.03) raw egg. The decline in total bacterial count and non-coliform count at week 4 could be attributed to the egg storage in a bio-secured environment of the laboratory before subjection to analyses. Yeast and molds were not observed across the eggs for all the weeks.

4.9 Effect of Egg Storage period on Whole Raw Egg Functional Properties

Table 4.9 shows the effect of egg **storage period** on the functional properties of raw eggs. There were significant differences (P<0.05) in functional properties of the raw eggs across the weeks for all properties. The highest (P<0.05) foaming capacities were recorded amongst weeks 1 to 3 (37.66, 35.61, 34.73) respectively. Week 1 raw egg had the highest (P<0.05) value for swelling capacity (114.57%). The highest values of week 1 for swelling capacity and emulsifying capacity might be a higher advantage over other weeks when egg-powder are incorporated in baking industries due to the freshness of the eggs as at when processed. Week 4 raw egg had significantly (P<0.05) highest values for foaming stability (84.57%) and lowest values for foaming capacity (28.22%). Weeks 1 and 4 raw eggs had the significantly (P<0.05) highest

Table 4.8: Effect of storage period on the microbial load/counts of raw eggs

	Storage period				
Parameters	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**SEM**
Total Bacterial Count (CFU/ml/g)	0.304^{b}	0.780^{d}	0.396^{c}	0.261^{a}	0.006
Total Coliform Count (CFU/ml/g)	0.00	0.00	0.00	0.00	0.00
Non-Coliform Count (CFU/ml/g)	0.03^{b}	0.49^{d}	0.12^{c}	0.01^{a}	0.03
Yeast Count	-ve	-ve	-ve	-ve	
Mold count	-ve	-ve	-ve	-ve	
Salmonella	+ve	+ve	+ve	+ve	
E. coli	-ve	-ve	-ve	-ve	

^{abcd}Means with different superscripts within rows differ significantly($P<0.05$), SEM= Standard error of mean

Table 4.9: Effect of egg storage period on the functional properties of raw eggs

	Storage period				
Parameters/Samples	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**SEM**
Emulsifying capacity %	26.77^{b}	29.85^{a}	26.00^{c}	26.18^{c}	0.54
Swelling capacity %	114.57^{a}	110.57^{b}	111.46^{b}	110.24^{b}	1.06
Foaming stability %	76.93^{b}	69.17^{c}	74.93^{b}	84.57^{a}	2.42
Foaming capacity %	37.66^{a}	35.61^{a}	34.73^{a}	28.22^{b}	1.84
Water Absorption capacity (g)	0.69^{b}	0.86^{a}	0.72^{b}	0.62^{c}	0.04
Oil Absorption capacity (g)	0.54^{a}	0.23^{b}	0.44^{a}	0.42^{a}	0.07
Water Retention capacity (g)	0.39^{b}	0.52^{a}	0.41^{b}	0.41^{b}	0.04
Oil Retention capacity (g)	0.39^{b}	0.52^{a}	0.41^{b}	0.43^{b}	0.04

^{abcd}Means with different superscripts within rows differ significantly($P<0.05$), SEM= Standard error of mean

values for oil absorption capacity (0.54, 0.42) respectively. Week 2 raw egg had the highest (P<0.05) values for water absorption capacity (0.86g), water retention capacity (0.52g) and oil retention capacity (0.52g).

4.10 Effect of Egg Storage period on Whole Egg Proximate Composition

Table 4.10 shows the effect of egg storage period on the proximate composition of whole egg powder. There were significant differences (P<0.05) across the treatments for dry matter, crude protein, lipid, ash and nitrogen free extract. The dry matter of the powder week 2 had significantly (P<0.05) highest values for dry matter and ether extract. The highest values for nitrogen free extract were recorded in powders obtained during week 3 (49.72%) and week 4 (49.82%). Week 4 powder significantly (P<0.05) had the highest value for ash (3.38%) while the lowest values were recorded in week 2 and 1 (1.76, 1.51%) powders respectively. The crude protein value decreased gradual across the weeks implying that the crude protein declined in bits as the raw eggs aged on a weekly basis before dehydrating to powder. They however fell within the ranges of 41.76-48.75% reported by Ndife *et al*. (2010), Koç *et al.* (2012), Marcelo *et al.* (2013), Sujata (2014) and Asaghar *et al.* (2015).

4.11 Effect of Egg Storage period on Functional Properties of Whole Egg Powder

Table 4.11 shows the effect of egg **storage period** on the microbial load/counts of whole egg powders. There were significant differences (P<0.05) across the treatments for total bacteria count and non-coliform count. Week 3 powder had the highest (P<0.05) values for total bacteria count while for non-coliform count, weeks 1, 2 and 3 powders have significantly higher (P<0.05) values than Week 4 with a value of 0.014. Across the treatments, *E. coli* and *Salmonella* were negative for all the whole egg powders. The observed level of coliforms across treatments however falls below the maximum allowable units as indicated in the revised guidelines for the

Table 4.10: Effect of egg storage period on the proximate composition of whole egg powder

	Storage period				
Nutrients	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**SEM**
Dry matter	89.89[d]	98.40[a]	93.27[c]	96.4[b]	0.91
Crude protein	50.96[a]	49.50[b]	43.54[c]	42.91[c]	0.65
Ether extract	5.01[a]	4.96[a]	3.90[b]	3.87[b]	0.32
Ash	1.51[c]	1.76[c]	2.83[b]	3.38[a]	0.16
Nitrogen Free Extract	42.52[c]	43.78[b]	49.72[a]	49.84[a]	0.54
Crude Fibre	0.00	0.00	0.00	0.00	0.00

[abcd]Means with different superscripts within rows differ significantly($P<0.05$), SEM= Standard error of mean

Table 4.11: Effect of egg storage period on the microbial load/counts of whole egg powder

	Storage period				
Parameters/Age	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**SEM**
Total Bacterial Count	0.190^{b}	0.136^{a}	0.242^{d}	0.234^{c}	0.001
Total Coliform Count	0.00	0.00	0.00	0.00	0.00
Non-Coliform Count	0.024^{b}	0.022^{b}	0.020^{b}	0.014^{a}	0.002
Yeast Count	-ve	-ve	-ve	-ve	
Mold count	-ve	-ve	-ve	-ve	
Salmonella	-ve	-ve	-ve	-ve	
E. coli	-ve	-ve	-ve	-ve	

^{abcd}Means with different superscripts within rows differ significantly($P<0.05$), SEM= Standard error of mean assessment of microbiological quality of eggs and egg products as described by Mnyandu, (2014).

4.12 Effect of Egg Storage period on Functional Properties of Whole Egg Powder

Table 4.12 shows the effect of egg storage period on the functional properties of whole egg powder. There were significant differences ($P<0.05$) across the weeks for foaming capacity, foaming stability, emulsifying capacity, swelling capacity, water Absorption capacity and oil absorption capacity. Week 4 had the significantly ($P<0.05$) highest values for foaming capacity (34.26%). weeks 3 and 4 had the significantly ($P<0.05$) highest values for foaming stability (85.00 and 85.17%). Week 1 had the significantly ($P<0.05$) highest values for emulsifying and swelling capacity (30.44 and 118.34%). Week 2 had the significantly ($P<0.05$) highest values for emulsifying capacity (29.41) which differed from weeks 3 and 4 (26.39 and 27.94). Water and oil absorption capacity (0.28, 0.33 and 0.29%) for weeks 1, 2 and 3 had significantly ($P<0.05$) higher values. Water retention capacity, oil retention capacity and bulk density were not significantly ($P<0.05$) different in all the weeks.

These results shows that whole egg powder made from week 4 eggs has viability and significantly higher functionality as compared to week 1 and in some cases with exceptions even as seen in foaming stability and foaming capacity.

4.13 Effect of Egg Storage period on Organoleptic Evaluation of Cakes

Table 4.13 shows the effect of egg storage period on cakes made from the whole egg powders. There were no significant differences ($P<0.05$) among the cakes in terms of colour, flavour, taste and general acceptability. The texture of cakes produced from eggs of Treatments 2 – 4 were however higher rated. The general results obtained however point to the fact that egg age did not negatively affect the outcome of the cake products.

Table 4.12: Effect of egg storage period on the functional properties of whole egg powder

	Storage period				
Parameters/Age	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**SEM**
Emulsifying capacity %	30.44[a]	29.41[ab]	26.39[bc]	27.94[b]	0.78
Swelling capacity %	118.34[a]	109.33[c]	109.98[c]	112.07[b]	1.17
Foaming stability %	73.80[b]	71.73[b]	85.00[a]	85.17[a]	5.34
Foaming capacity %	30.41[c]	32.17[b]	31.90[b]	34.26[a]	0.47
Bulk density (g/ml)	0.000	0.003	0.003	0.003	0.003
Water Absorption capacity (g)	0.28[ab]	0.33[a]	0.29[ab]	0.26[bc]	0.03
Oil Absorption capacity (g)	0.28[ab]	0.33[a]	0.29[ab]	0.26[bc]	0.03
Water Retention capacity (g)	0.28	0.29	0.29	0.24	0.04
Oil Retention capacity (g)	0.28	0.29	0.29	0.24	0.04

[abcd]Means with different superscripts within rows differ significantly($P<0.05$), SEM= Standard error of mean

Table 4.13: Effect of egg storage period on the organoleptic properties of cakes

	Storage period				
Parameters	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**SEM**
Colour	5.10	5.57	5.27	5.17	0.89
Flavour	4.53	4.73	5.07	5.07	1.19
Texture	4.40^{b}	5.57^{ab}	5.20^{ab}	5.47^{a}	1.08
Taste	6.43	6.23	6.40	6.70	1.01
Acceptability	7.07	6.83	7.10	7.20	0.93

^{abcd}Means with different superscripts within rows differ significantly($P<0.05$), SEM= Standard error of mean

4.14 Effect of Egg Storage period on Organoleptic Evaluation of Cookies

Table 4.14 shows the effect of storage period on cookies made from whole egg powders. There were no significant ($P<0.05$) differences in cookies within the treatments for flavour, texture, taste and general acceptability. However for colour, week 4 had significantly ($P<0.05$) highest value (6.10) as compared to treatment 1 which had significantly ($P<0.05$) lowest value (4.97) while weeks 2 and 3 were ($P<0.05$) similar to week 1. The significant ($P<0.05$) difference in colour is based on its appeal; the panelists showed preference for the lighter colour of week 4. Browning in the cookie samples could have been due to Maillard-type reactions (Potter and Hotchkiss, 2006) resulting from the presence of reducing sugars, proteins and amino acids and caramelization due to the effect of severe heating during processing (Mannay and Shadaksharaswany, 2005) which is also similar to Ndife *et al.* (2014) results.

Table 4.14: Effect of egg storage period on the organoleptic properties of cookies

	Storage period				
Parameters	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**SEM**
Colour	4.97 [b]	5.33[ab]	5.50[ab]	6.1[a]	0.89
Flavour	3.27	3.27	3.53	3.90	0.99
Texture	6.40	6.50	6.37	6.87	1.04
Taste	4.33	3.63	4.33	4.30	1.17
Acceptability	4.33	4.17	4.47	4.63	1.06

[ab]Means with different superscripts within rows differ significantly($P<0.05$), SEM= Standard error of mean

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. Production of egg powder with the aid of a dehydrator and freeze drier was established.
2. The yield percent of 1000g raw egg from freeze dried, dehydrator and commercial egg powder were 23.1%, 22.4% and 26.7% respectively.
3. Freeze dried and dehydrated whole egg powders compare favourably with the commercial (imported-standard) whole egg powder in all spheres of evaluation.
4. Eggs of three weeks (21 days) of age are not a total write-off for egg producing farmers as laboratory and product evaluations indicate their suitability for use as egg powder.
5. Cakes and cookies (confectionary products) made from dehydrated whole egg powder were edible and acceptable.

5.2 Recommendations

1. Dehydrator use for egg powder production is effective and can be adopted by home users as much as producers.
2. Farmers experiencing egg glut can opt to selling their eggs to egg powder producers after three weeks at discounted price instead of total revenue losses.
3. Whole egg powders can be utilized by confectionary industries for their baked products.
4. Further studies can be carried out in evaluating the nutritional value of products made from egg powder.

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APPENDICES

SENSORY EVALUATION SHEET

GENDER…..... **PHONE NO**……

Instruction: Before you are coded samples which you are to taste and critically observe each sample and give your Inference in the appropriate format below for individual factors in the columns.Please tick your level of preference for each palatability trait of the given samples

INDEX	COLOUR					FLAVOUR					TEXTURE					TASTE					ACCEPTABILITY				
SAMPLES		1	2	3	4		1	2	3	4		1	2	3	4		1	2	3	4		1	2	3	4
1	Extremely Dark					Not Perceptible					Extremely Tough					Extremely Coarse					Dislike Extermely				
2	Very Dark					Just Perceptible					Very Tough					Very Coarse					Dislike Very Much				
3	Moderately Dark					Moderately Perceptible					Moderately Tough					Moderately Coarse					Dislike Moderately				
4	Slightly Dark					Slightly Perceptible					Slightly Touch					Slightly Coarse					Dislike Slightly				
5	Intermediate					Intermediate					Intermediate					Intermediate					Intermediate				
6	Slightly Light					Slightly Intense					Slightly Tender					Slightly Fine					Like Slightly				
7	Moderately Light					Moderately Intense					Moderately Tender					Moderately Fine					Like Moderately				
8	Very Light					Strongly Intense					Very Tender					Very Fine					Like Very Much				
9	Extremely Light					Extremely Intense					Extremely Tender					Extremely Fine					Like Extremely				