Effect of Drying Methods and Egg Types on Basic Quality and Shelf Stability of Whole Egg Powder

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Declaration

I, the undersigned, declare that this thesis titled "**Effect of Drying Methods and Egg Types on Basic Quality and Shelf Stability of Whole Egg Powder**" has been carried out and written by me in the Center for Food Science and Nutrition, Addis Ababa University, Addis Ababa, under the supervision of **Dr. Kaleab Baye** and **Dr. Paulos Getachew**. 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.

_______________________ _______________________

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List of Abbreviations and Acronyms

ANOVA	Analysis of Variance
AOAC	Association of Analytical Chemists
DZARC	Debrezeit Agricultural Research Center
EIAR	Ethiopian Institute of Agricultural Research
EW	Egg White
EY	Egg Yolk
FA	Fatty Acid
FDA	Food and Drug Administration
FEV	Food Energy Value
GDP	Growth and Development Plan
HDL	High-Density Lipoprotein
LMICs	Low and Middle Income Countries
LDL	Low-Density Lipoprotein
MUFA	Mono Unsaturated Fatty Acid
NESNS	National Epidemiological Surveillance Network of Spain
PUFA	Poly Unsaturated Fatty Acids
PEM	Protein Energy Malnutrition
RUTF	Ready to Use Therapeutic Foods
SFU	Saturated Fatty Acid
SNFRC	Sebeta National Fishery Research Center
SPC	Soluble Protein Content
SPSS	Statistical Packaging for Social Sciences
TAMB	Total Aerobic Mesophilic Bacteria
UNECE	United Nation Economic Commission for Europe
WAC	Water Absorption Capacity
WEP	Whole Egg Powder

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Author Biography

The author was born on February 21, 1983, E.C. at Addis Ababa, Ethiopia from his father Abrha Woldu, and his mother Almaz Hailesslasie. He attended elementary school education from 1990 to 1997 E.C. Then he continued with secondary and Preparatory School education at Atsela Secondary and Preparatory School from 1998 to 2001 E.C. Then he joined Hawassa University on October 05, 2002, E.C. and graduated with a B.Sc. degree in Applied Chemistry on July 07, 2004, E.C. After graduation, he was employed by Ethiopian Institute of Agricultural Research on May 14, 2006, E.C and served as Assistant Researcher II in Food Science and Nutrition Program at Holetta Agricultural Research Center until he joined Addis Ababa University for M.Sc. study at the Center for Food Science and Nutrition on October 01, 2011, E.C. Currently the active contact address of the author is e-mail-esayasabrha@ymail.com or robelabrha11@gmail.com. Finally, the author will serve the research center after completing his M.Sc. study as per the agreement between the institute and the author.

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Abstract

Weak market linkages, unavailability of cold-storage, and the significant loss of eggs due to breakage and low shelf-life contribute to the unaffordability and the low consumption of eggs in low-income countries like Ethiopia. Powdered dried egg provides a convenient alternative to this problem. The effect of spray- and oven-drying of eggs from local (Ethiopian) and exotic (imported) chicken breeds on the physical, techno-functional, nutritional composition, shelf stability, and organoleptic attributes of egg-powders was evaluated. Exotic (n= 150) and local (n= 140) eggs were spray/oven-dried. Experimental design used was completely randomized design. The yield, bulk-density, flowability, and the foaming-, emulsification-, and water/oil absorption- capacity of the egg powders were evaluated following standard procedures. The concentrations in energy, protein, fat, ash, and minerals were determined. The egg-powders' contribution to nutrient requirements from complementary foods and their potential use as an alternative protein source in ready to use therapeutic foods (RUTF) were evaluated. Local eggs had higher energy and fat content, whereas protein was higher in the exotic eggs (P< 0.05). About 12.5 g of egg powder (one egg) can fulfill > 75%, 30%, and 40% of fat, energy, and calcium requirements, respectively. Only 6 g and 4 g of egg-powder (local/exotic eggs with oven/spray drying) are needed to fulfill protein and choline requirements, respectively. Considering the quality/quantity of proteins, egg powders can be alternative protein sources in ready to use therapeutic foods (RUTFs). Functional properties including emulsification capacity, water/oil absorption capacity, and soluble protein content between oven-dried local and exotic eggs were significantly different (p<0.05). However, this trend was no observed for the spray-dried powder (p<0.05). The sensorial quality of the whole egg powder was acceptable. Whole egg powders from local eggs generally had the highest (p<0.05) overall organoleptic rating. The total aerobic mesophilic bacteria and total coliforms were in the range of (2-7) and (0.42-5) CFU/g respectively over the storage period of dried whole egg. Salmonella was also absent during the storage period of dried whole egg. In conclusion, drying eggs into powder can constitute a food systems' intervention that improves the safety and quality of diets, reduce loss, and increase eggs' affordability in low-income countries like Ethiopia. In general, whole egg powders produced by spray and oven drying methods are generally accepted and serve as good alternatives to fresh eggs

Keywords: *whole egg powder, food systems, affordability, nutrient composition, protein, complimentary food*

1. Introduction

1.1. Background and Justification

Child malnutrition is highly prevalent in low and middle-income countries (LMICs) as reflected by growth faltering, nutritional deficiencies, and the related poor cognitive outcomes (Perez-Escamilla *et al*., 2018). The timing of child growth faltering illustrates that poor complementary feeding is a key determinant (Victora *et al*., 2010). Indeed, a large majority of children in LMICs have suboptimal diets, characterized by low consumption of fruits, vegetables, and nutrient-dense animal source foods (Baye and Kennedy, 2020). Low dietary diversity, particularly the low consumption of animal source foods has consistently been linked to child stunting (Headey *et al*., 2018; Krasevec *et al*., 2017).

Egg is one of the most versatile and nutrient-dense food that, relative to other animal source foods, is more available and accessible (Iannotti *et al*., 2014). For example, poultry is among the most widely owned livestock in LMICs like Ethiopia, but paradoxically they are still unaffordable for a large share of the population in LMICs (Headey and Alderman, 2019; Yimer *et al*., 2017). The poor infrastructure (e.g. absence of cold-chain) and the weak market linkages in countries like Ethiopia, complemented with the low shelf-life of eggs and the significant loss due to breakage during transportation and storage increases the price of eggs; hence, constraining consumption and benefits to child growth and cognition (Hailemichael *et al*., 2016; Iannotti *et al*., 2017). As a result, along with increasing production and creating demand for eggs, innovations that reduce transaction costs related to transportation and breakage of eggs, as well as improving shelf-life is critical.

In various food industries eggs are broadly used as ingredients for the preparations of egg recipe food products. Particularly, egg yolk is indubitably an efficient ingredient in many food products for its functional, nutritional, and organoleptic properties. Indeed, the egg contains proteins of high biological value and extra nutrients (vitamins, minerals, essential fatty acids, and phospholipids) (Anton, 2013; King'ori, 2012). Whereas egg white is an anticipated ingredient for many foods such as bakery products, meringues, and meal products, as a result of its excellent foaming and gelling properties. The availability, accessibility, and better livelihood option of an egg throughout the year require appropriate storage and preservation technologies. In another way, fresh eggs are difficult to transport because of their bulkiness, fragility, and highly perishable nature (Akpinar-

Bayizit *et al*., 2010). Hence, egg in powder form provides a near-complete elucidation to these problems. Drying is a widely used food preservation method applied in several foods including meat, cereals, fruits, and vegetables by rural households (Sagar and Kumar, 2010).

Drying eggs into powder offers numerous advantages, including easier dosage for the use of eggs as ingredients in mixed dishes and food formulation, easy for transport and storage, and making safe against microbial growth (Bergquist, 1995b). Egg powder is nutrient-dense and is able to use for the food-to-food fortification of complementary foods or possibly as alternative protein sources in ready-to-use therapeutic foods (RUTF). However, evidence evaluating this potential is scarce and usage of egg powders is not common in LMICs, partly because of their low availability. According to Mine, (1995) during egg white powder production, the proteins are exposed to several processing steps like thermal, physical, interfacial, and chemical treatments that may damage egg white functional properties.

In Ethiopia, two types of eggs are recognized by lay consumers: i) the larger eggs with lighter yellow yolk known as *Ferengi* eggs and obtained from imported breeds (exotic), and; ii) the smaller eggs with deep-yellow colored yolk known as *Habesha* (local) egg. Despite this differentiation and consumer preference for the local egg, little information exists about the difference in nutritional and techno-functional composition of these two egg types, and how they are impacted by the oven and spray drying. Such information is timely and can inform food systems' interventions that aim to improve the adoption of healthy diets.

The quality and safety of whole egg powder depend on two critical steps: which are the drying process and the storage (Caboni *et al*., 2005). Recently, there has been an increased demand for dried egg products in the food industry for ready-to-use products and handling considerations. Several processing and preservation methods like spray drying, oven drying, and freeze-drying techniques have been adopted with advantages and disadvantages on the qualities of the products (Akpinar-Bayizit *et al*., 2010). There are also reports on the influence of storage conditions on the physical and functional properties of the dried egg. In an attempt to address the low acceptability of egg powder due to unfamiliar taste, egg powder could be processed into egg-based food products by adapting local recipes of egg-based products (Khoza, 2014). As (Mnyandu *et al*., 2014) finding reported that some of the ingredients of these products could mask the unfamiliar sensory properties of egg powder, including the unfamiliar taste.

Therefore, this study aimed to evaluate the effect of drying methods (spray- and oven-drying) and egg types (Ethiopian local and exotic) eggs on the physical, techno-functional, and nutritional quality of the whole egg powder. The contribution of egg powders to meeting children's nutritional requirements has also been calculated. The shelf-stability of dried whole egg powder was also evaluated at temperate and tropical temperatures using plastic cups and aluminum foil as storage materials.

1.2. Statement of the Problem

Since, in low and middle income countries the consumption of animal source foods is low, huge attention has been shifted to poultry farming mostly for egg production in the light of the current recession for thier low demand on the production system relative to livestock. Eventhough, the increasing in the production of an egg to resolve the scarce for the animal source based food is a prime option, several challenges; awareness of the people on the production and handling, limited resource for feeding; struggle to provide sufficient shelter and treatment for their flocks' hens. In addition to this farmers have been challenged with a major setback in the management of eggs after production thereby leading to egg-glut. As aresult of this egg glut over a while results in a compromise of egg quality (deterioration and spoilage)

Egg by its nature, it is a highly nutritious food product. It has the potential to improve the nutritional status of individuals who are at risk of Protein Energy Malnutrition in rural households (Khoza, 2014). However, since the egg is a highly perishable food type, it is not a widely applicable in the long run for serving as a nutritional source. Thus, the utilization of eggs as a source of nutritious food is a major problem for most households. For this reason egg in the form of powder could be a feasible preserved product that can address such a challenge due to its increased shelf-life, nutrient density, and ease of transportation and storage (Bergquist, 1995a).

In an attempt to this Daramola, (2018) also stated that the transportation of 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. Because of these problems observed in wide, this research was conducted to enables an alternative option to provide a shelf-stable, affordable, nutritious, and sensorial acceptable product using different drying methods and egg types.

1.3. Objectives

1.3.1. General Objective

To develop egg powder and to conduct a comparative evaluation of the effect of different drying methods and egg types on the quality and shelf stability of egg powders

1.3.2. The Specific Objective of this study were to;

- Produce whole egg powders from local and exotic eggs through spray and oven drying
- Compare the yield, physical characteristics, proximate composition, and functional properties of whole egg powders
- Evaluate the mineral composition of the whole egg powders
- Compare the organoleptic property of the whole egg powders
- Determine the shelf stability of the whole egg powders during storage

1.4. Research Questions

- Is different drying methods have an impact on the nutritional composition, sensory attributes, functional property and shelf stability of the whole egg powder?
- Dose the different types of an egg (habesha and foreign) have an impact on the nutritional composition, sensory attributes, functional property and shelf stability of the whole egg powder?
- What storage condition can maintain a good shelf stability of the whole egg powder?
- Is the dried whole egg powder product has sensorial acceptable?

1.5. Significancy of the Study

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 food and confectionary industries. Besides this, egg in the form of powder provides a friendly applicability to those food industries.

The finding of this research enables the use of a shelf-stable, nutritious, and easy to handle egg product as a supplement with other widely consumed products like Shiro, bread, and others which are more widely consumed foods by the majority of the rural household peoples.

To further implement those, suitable drying methods and storage conditions were provided to get a shelf-stable and sensorial accepted product. This also provides an alternative good option for the peoples suffering against protein-energy malnutrition.

Farmers experiencing to egg wastage especially during the fasting period can opt to sell their eggs to egg powder producers to escape the total revenue losses.

The economic feasibility was also validated in terms of its nutritional composition of the egg with its daily requirements per a given egg, half of the egg, and one-third of an egg.

1.6. Scope and Lmitation of the Study

The present study has several strengths and limitations. To our knowledge, this is the first study analyzing the nutritional composition and functional property of local (*Habesha*) eggs, and comparing it to exotic eggs for which data is ample. The drying of whole egg powder using two alternative drying procedures, one suitable for industrial and the other for smaller scale (including households) and the evaluation of the contribution of egg powder as ingredients in complementary foods and RUTFs is of direct application and can inform much-needed food systems' interventions in countries like Ethiopia. The study could not, however, analyze all relevant nutrients because of technical and financial constraints. Changes in the amino acid composition, vitamins, the integrity of the proteins, and the stability of the techno-functional and nutritional properties during storage will need to be studied.

Notwithstanding the above limitations, the present study illustrates that both the spray and oven drying of local and exotic eggs can yield good quality whole egg powders that can extend the shelf-life, reduce transportation cost and storage space, and contribute meaningfully to nutrient intake. Besides, with proper packaging and storage, it can improve food safety. The promotion of drying of eggs into powder can constitute a food systems' intervention that can improve the quality of diets, reduce loss, and make eggs more affordable in LMICs like Ethiopia.

2. Literature Review

2.1. Hen and Egg Production in Ethiopia

In the Ethiopian context poultry is effectively considered as domestic fowl ('chicken'). However, in no part of the accessible data, there is much confusion in the extent of the national flock. Short-term fluctuations in poultry numbers have been more marked than those of ruminant species but an upward trend of 2.5% per year was considered to have been achieved that pushed numbers from approximately 14.2 million in 1981 to more than 32 million in 2005 (ESA, 2011). Exceptionally Ethiopia is own more cattle (mainly as work oxen) in the households over much of its territory than any other domestic livestock species.

Ethiopia has about 60% of the total chicken population of East Africa and from this, more than 95% of this population and practice scavenging management have been kept by rural smallholder farmers (Mekonnen *et al*., 1991). In the twelve administrative zones (sub-regional entities) of the Oromia Region, over 95% of households own cattle whereas only 59% own poultry (ESA, 2011). Poultry ownership among zones in Oromia varies from 32 to 74% of households, which at a micro-level in some Oromia zones (this may or may not be representative of other areas *(Stein et al*., 2009).In another study, five ecotypes from different areas were labeled as Tilili from southern Amhara, Horro from western Oromia, Chefe from central Oromia, Jarso from north-eastern Oromia, and Tepi from Southern Nations and Nationalities Peoples Region *(Tadelle et al*., 2003). In yet a third study, seven so-called ecotypes from Amhara Region in north-western Ethiopia were identified as Tilili, Gellilia, Debre-Ellias, Mello-Hamusit, Gassay, Guangua, and Mecha (Hassen *et al*., 2006).

Egg production varies throughout the year. Many factors are attributed to variations, such as age, breed, feed, climate, and body weight (Mutayoba *et al*., 2011). In winter, egg production tends to be lower (Watson, 2011). for instance, according to (Dessie and Ogle, 2001) report, the annual egg production is 55-80 eggs per year in 5-6 clutches of 10-15 eggs with an average weight of 30 g. In five areas of the highlands, an additional study showed a somewhat higher production of 17 eggs in the first clutch, 21 in the second and 25 for third, and all other clutches with 2.6 clutches being laid per year (Tadelle *et al*., 2003). FAO data indicate that the poultry meat production can be increased by about 45% between 1993 and 2006 (Wilson, 2010) and its ease of use per person by about 4.5% which is very much below the world average. Data for 1990 suggest that annual national production was about 79,120 tons of eggs and 76,560 tons of meat.

2.2. Hen and Egg Consumption in Ethiopia

Hen meat and eggs are consumed readily in the highlands than in the lowlands. Even though the intake of eggs has a potential to decrease child and adult malnutrition, research has shown that most rural consumers perceive eggs as a portion of food consumed for luxury and as a source of income, rather than as an important protein source for their households (Aklilu *et al*., 2008; Alders and Pym, 2009). According to (Molla, 2010) eggs are perceived as an essential food commodity that should be served to visitors, and when household members are sick. Eggs, to a certain extent, are associated with households with high social-economic status. Ethiopians consume more eggs per person than any other country in Africa. Even though consumption level is quite very low by world standards. But, as (Aklilu *et al*., 2008) reported that egg consumption is uncommon among the Ethiopian poor community as it is considered a luxury.

Many of the eggs consumed in Ethiopia are in the form of 'Douro wat' which is a very popular spicy chicken and egg stew. At the household level 50% of eggs are set under hens to produce replacement birds, 27% are sold and 23% are eaten at home, and about 30.6% of mature birds are kept as replacements, 44.4% are sold and 20% is used for home consumption *(*Tadelle *et al*., 2003). Besides this, some hens may be kept beyond their useful life for socio-religious reasons and others may be consumed for health reasons as prescribed by traditional healers (Tadelle *et al*., 2003). Consumers devastatingly prefer local to exotic hens and eggs, and hence, in local markets, an indigenous bird of 1.25 kg live weight and its 40 g eggs (or lighter) command the same prices as exotic birds of 1.5 kg and eggs of 60 g. The premium for local birds is attributed to better meat flavor and more deeply colored egg yolks (Dessie *et al*., 2003).

2.3. Composition of Eggs

The foremost and physical components of eggs include eggshell, egg membrane, egg white, egg yolk, and air cell. FAO (2015) cited by Sharif *et al*., (2018) reported that both the white and the yolk are complex mixtures and much uncertainty exists as to the nature of their elements. They contain numerous appreciable proteins and triglycerides, and phosphatides in the yolk. Phosphorus exists in protein, phosphatide, and inorganic combination, the organic phosphorus being present in such a considerable amount as to cause a marked excess of acids over bases on ashing.

Table 1: Physical and Nutritional Compositions of Eggs from Hen

Component	Unit	Amount	Component	Unit	Amount
Eggshell	%	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	Phosphors	mg	180.0
Energy	kcal	162	Zinc	mg	1.44
Protein	g	12.2	Potassium	mg	147
Carbohydrate	g	0.68	Selenium	µg	10
Lipids	g	12.1	Folic acid	mg	65.0
Carotenoids	µg	10	Iodine	µg	12.7
Cholesterol	mg	410	Tocopherol	µg	1.93

Source: Daramola, (2018)

2.3.1. Egg Shell

Eggshell color is caused by pigment deposition during egg formation in the oviduct and can vary according to classes 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 relation between shell color and nutritional value, there is often a cultural preference for one color over another. A report by 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, perceptible when one peels a boiled egg. Eggshell the 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 the egg membrane as a wound healing cure. The traditional folk cure of dressing a wound with chicken-egg membrane treatment (the outer shell membrane) acts to accelerate the early stages of wound healing (Ahmed *et al*., 2019). 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. Whole Egg

A whole egg is a combination of egg white and egg yolk. It's recognized as one of the best and cheapest sources of high-quality protein which contains a delightful source of essential amino acids for our body building (Caner, 2005; Kassis *et al*., 2010). A whole egg is a basic food material that is always in demand and consumed worldwide. It has a substantial place in the food industry due to its functional properties, such as emulsification, foaming, and gelling. The transport and storage of powdered egg are less costly and requires less space; at low moisture content, the powdered egg is less susceptible to microbial growth; and the uniformity and easy dosage of powdered eggs make them an ideal ingredient in the food industry.

2.3.4. Egg White

(Karadas *et al*., 2006) conveyed that the clear liquid (also called the albumen or the glair) enclosed within an egg was named egg white. The primary natural tenacity of egg white is to protect the yolk and provide additional nutrition for the growth of the embryo (Alessandro *et al*., 2010). Egg white is a key ingredient in many food products as it combines high nutritional quality (Van-Immerseel *et al*., 2011) with excellent functional properties (Nys *et al*., 2011). However, egg white is also one of the leading causes of IgE-mediated food allergy in childhood (Moneret, 2008). Many studies carried by the following authors (Baron *et al*., 2003; Desfougères *et al*., 2008; Hammershøj *et al*., 2006) have been investigated that the effect of dry heating on foaming and gelling properties of either egg white, or purified egg white proteins.

2.3.5. Egg Yolk

Egg yolks contain generous concentrations of greatly bioavailable carotenoids, especially the xanthophyll's, lutein, and zeaxanthin (Handelman *et al*., 1999). Chicken eggshells, which first aids to protect and deliver nutrients to the enclosed embryo (Schaafsma *et al*., 2000), and have been used by humans for a long period as a food additive, but on a very modest scale. Egg yolk color is dependent on the diet of the hen; especially on plant pigments. Among the pigments, lutein is the most abundant pigment in egg yolk.

2.4. Nutritional Composition and Characteristic of Whole Egg

Liquid whole egg, naturally containing 24% dry matter (12.5% protein, 9.9% fat, 0.73% carbohydrate, 0.87% ash) (Yilmazer *et al*., 2011). As Nys, (2001) reported egg contains over 11%

lipids, mainly concentrated in the yolk (about 33% to 35%), whose fatty acids are more unsaturated than those of most animal lipids.

Eggs are a conventional food containing nutrients that play fundamental roles beyond basic nutrition, their promotion as functional foods should be considered (Herron and Fernandez, 2004). Eggs are of particular interest from a functionality point of view because they offer a moderate calorie source, 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. 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).

Table 2: Egg white, egg yolk, and whole egg nutritional composition (%)

Egg component	Water	Protein	Lipid	Carbohydrates	Vitamin & Ash
Egg White	88	10.6	0	0.9	0.5
Egg Yolk	51.1	16	30.6	0.6	1.7
Whole Egg	75.6	12.8	10.5	0.3	0.8

Source: (Guérin-Dubiard et al., 2010)

Hen egg yolk encloses high amounts of lipids has strong interest to lower the ratio of n6/n3 fatty acids in the human diet, to reduce the risk of chronic diseases, which are prevalent in the western societies (EFSA *et al*., 2010; Meynier *et al*., 2014). The supplementation of hen diet with flax seeds, fish oils, and other feed ingredients has been proved to reduce this ratio, thus increasing the proportion of n_3 PUFA in egg yolk (Baucells *et al*., 2000; Fraeye *et al*., 2012; Milinsk *et al*., 2003). The total dry matter of freshly laid egg yolk is about 52% ± 0.2%, and increases slightly as the laying hen gets older: an average 2% increase has been observed. The largest variation of egg yolk's dry matter takes place during storage of the eggs in their shell, because of the transfer of water from the white into the yolk (Guilmineau, 2007).

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. 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).

Table 3: Detailed average nutritional composition of fresh egg yolk

component	subgroup	Main molecules	Content (%w/w)
water			48
Lipids (34%)	Triglycerides	FA (C16:0), PUFA (C18:2), MUFA (C18:1)	22.6
	Phospholipids	Phosphatidylcholine (Lecithin)	7.0
	(9.6%)	Phosphatidylethanolamine	1.4
		Sphingomyelin	0.6
		Lysophosphatidylcholine	0.2
		Lysophosphatidylethanolamine	0.2
		Plasmogen	0.1
		Inositol Phospholipid	0.01
	Sterols	Mainly cholesterol	1.8
Proteins (16%)		Phosvitin	1.8
		Livetins	5.0
		Lipovitellin = HDL	5.8
		Lipovitellinin = LDL	3.5
Carbohydrates		Free glucose	0.2
Vitamins		Vit. A, D, E, K, B1, B2, B3…	0.8
Minerals		P, Ca, Na, K, Cl, S, Mg, Fe	1.0

FA: fatty acid; PUFA: polyunsaturated fatty acid; MUFA: monounsaturated fatty acid; w/w: weight by weight; HDL: high density lipoprotein; LDL: low density lipoprotein

Source: Acker and Ternes, (1994); Burley, (1989); Guilmineau, (2008).

2.5. Egg Powder

Egg powder is eggs in powdered form which is fully dehydrated (Lechevalier *et al*., 2011). According to (Lechevalier *et al*., 2013; Phillips and Williams, 2011) egg powders are used extensively in bakery foods, mayonnaise, salad dressings, confectionaries, pasta, and many convenience foods. The industrial treatment conducted for whole egg and egg yolk differs from the one used for egg white: in which whole egg and egg yolk require a pasteurization step before drying, which is not necessary for egg white because this operation is realized in the dry state (Galet *et al.*, 2010a). The overall conditions come upon during the thermal treatments are vulnerable to change the functional properties of egg products, mostly by decreasing the protein solubility (Galet *et al.*, 2010a). Egg powder is preferred over traditional liquid eggs because it provides a convenient alternative to fresh eggs due to its nutritional and functional properties, increased shelf life and refrigerator not required for storage, easy transportation, and handling, and also its microbial safety (Board, 2012). Egg white powders produced by spray drying which are commercially available and more or less commercially available whipping egg white may have a whipping aid, such as sodium hydrogen sulfate, triethyl citrate, xanthan gum, or sodium oxalate used at about 0.1% based on the egg white solids (Phillips and Williams, 2011).

2.6. Processing Methods for Egg Powder Production

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 (Asgar and Abbas, 2012). Irrespective of the method adopted, it has the potential for longer shelf life (Kiermeier *et al*., 2004). Nowadays different drying technologies have been applicable for the production of whole egg, egg yolk, and egg white powder products. Some of them like foam-mat drying, pan drying, belt drying, spray drying, freeze-drying, and hot air (oven) was applied within their specific criteria and their limitations.

Foam-mat drying is an old technology used to develop hard-to-dry materials, obtain products of preferred properties (Kudra and Ratti, 2006) (i.e., favorable rehydration, controlled density), and to retain volatiles that otherwise would be lost during the drying of non-foamed materials. The principle is to dehydrate a liquid concentrate along with or without foam stabilizer in foam mat form (Thirupathi *et al*., 2008). Foaming is implemented by injecting gas (such as CO_2, nitrogen, or air) into the liquid before the drying process takes place in the spray dryers, plate dryers, or band dryers, or before conventional freeze-drying, or the microwave drying of frozen foams (Kudra and Ratti, 2006). Compared to spray drying, foam-mat drying requires less time, less energy, lesser production costs, and no need for concentration (Thirupathi *et al*., 2008).

Pan is a traditional technology called pan drying is still used to produce flake-type egg white products (Lechevalier *et al*., 2013). Glucose-free and concentrated egg white are placed on plates in a hot room (54°C maximum temperature) in which slow concentration and drying occur without coagulation. This product needs at least 24 h to rehydrate and is mainly used for aerated confectioneries.

Belt-drying is a method that was used in China to produce dried whole egg and egg yolk (Lechevalier *et al*., 2013). The liquid was a blowout as a thin film on a continuous aluminum belt moving through a hot air system. This manner was also used to produce egg white solids: egg white is foamed and then dried on the belt. However, due to technological advancement in the performance, operations, large scale capacities, and safety of drying technologies, those drying methods have not been used widely now on egg powder production.

Most of the research work in kinds of literature about egg powder is related to the spray drying process conditions and their effects on the functional, physical, and chemical properties of egg powder (Caboni *et al*., 2005; Franke and Kießling, 2002; Hammershøj *et al*., 2004; Lechevalier *et al*., 2007). The results were confirmed by (Ayadi *et al*., 2008) on whole egg powders. Egg yolk freeze- or spray-drying to 98–99% dry matter increases the carotenoid content, because of the degradation of binding proteins, followed by a release of associated xanthophyll's that were not previously extractable (Wenzel *et al*., 2010).

2.6.1. Spray Drying

Among several encapsulation techniques, spray drying is the most widely used and low-cost method to produce a food powder (Desai *et al*., 2005). Spray drying is a unit operation widely used in the food industry (Loh *et al*., 2005). It can be regarded as an environmentally correct technology at the lowest cost which providing a new processing method of eggs (Cusidó and Cremades, 2012). It is one of the techniques frequently used to obtain powdered eggs from liquid eggs (Ayadi *et al*., 2008). The impact of warm air treatments on the odor quality of egg powder components has rarely been studied, by either sensory analysis or olfactometry. It seems that spray-drying does not significantly impact the flavor and aroma of egg products (Ayadi *et al*., 2008) but the escalation in the spray-drying temperature could result in a greater loss of PUFAs.

In his study (Franke and Kießling, 2002) also demonstrated that higher temperatures during spray drying lead to a considerable decrease in the foaming properties of the dried whole egg the capability of emulsion stabilization were increased. Franke and Kießling, (2002) also demonstrated on a pilot study of spray dryer that the increase of inlet air temperature improved the capacity of whole egg powders to stabilize emulsions. Accordingly, (Lechevalier *et al*., 2007) have also shown that the detrimental effect of spray drying on the foaming properties of egg white is due to heat transfer, and not too trim rates during spraying.

2.6.2. Freeze Drying

Freeze drying is a moderate technology particularly proper for aromatic and/ or heat-sensitive products, with the technology in which water is detached from the product, while it is frozen by subjecting it to a very high vacuum: this is based on a direct phase transition from ice to vapor (Jaekel *et al*., 2008). However, even if it is costly due to the latent heat requirement, a freeze-drying process for egg yolk has recently been developed, producing a powder with technological and organoleptic properties equivalent to those of refrigerated liquid egg yolk (Jaekel *et al*., 2008). Freeze drying is carried out by dehydration to sublimation of the water from the product by freezing it. Duo to the absence of liquid water and the low temperature required for the process, most deterioration and microbiological reactions are retarded which results in a freeze-dried product of usually high quality (Rawson *et al*., 2011). Some authors like (Jaekel *et al*., 2008) favored that freeze-drying to preserve the functional properties of egg yolk.

Table 4: percentage(%) of Moisture, ash, and protein obtained for WE, EY, and EW freeze-dried samples [a]

Sample	Moisture	Ash	Protein
WE	6.07+0.13	3.29+0.11	48.75+0.31
EY	3.75+0.16	3.45+1.14	31.19+2.44
EW	8.03+1.52	4.55+0.15	81.00+1.18

Values represent the means of triplicate sample analysis results with respective standard deviations, WE: whole egg; EY: egg yolk; EW: egg white

Source: Jesús et al., (2013)

2.6.3. Dehydration (Oven) Drying

Hot-air-dried products can have a prolonged shelf life. But, unfortunately, the worth of the dried product is usually reduced related to the original foodstuff (Ratti, 2001) as a result of the high temperature used during the drying process. The oven-drying method affected some of the functional properties of the dried egg components. The emulsification capacity of egg yolk powder which is 74.00% and stability of 72.40% were highest than whole egg and egg white powders respectively. On the other hand, the egg white powder gave the lowest values of emulsification capacity which is 17.77 and 14.70% (Ndife *et al*., 2010).In the baking industry, ingredients work in collaboration to obtain the desired texture and structure of bakery products (Abdullah, 2008). Dehydrated foods offer not only cost savings but the peace of mind of knowing exactly what the consumer aims at serving the consumers for the coming food riots.

Table 5; Percentage of nutrient contents and food energy value (g/Cal) of whole egg and its components oven-dried at. 44°C

	Protein	Fat	Moisture	Ash	Carbohydrate	FEV
Whole Egg	45.21	8.94	6.74	1.02	38.09	413.66
Egg Yolk	26.20	27.62	3.88	0.60	41.70	520.18
Egg White	62.04	7.17	4.32	1.00	25.48	414.52

FEV = Food Energy Value

Source: (Ndife et al., 2010)

As (Ndife *et al*., 2010) reported that the whole egg powder, egg yolk powder, and egg white powder that can be produced using the oven drying method at a meticulous temperature of 44°C without any adverse effect on their functional and nutritional properties. From now onwards, they could be assimilated as nutritive ingredients in the production of healthy food products.

2.7. Quality of Whole Egg Powder

Egg powder is high in protein, carbohydrate, and energy (Board, 2012), a 100g of egg powder contains approximately 55g of protein, 22g of carbohydrates, and 450g calories. Egg dehydration eliminates the growth of micro-organisms in the egg product (Campbell *et al*., 2009). As Doyle, (2009); Sperber, (2009) also argue that although egg dehydration minimizes the presence of micro-organisms, some micro-organisms can survive the drying process and may be able to grow if the product is not packaged, stored, and held in a manner that prevents water from entering the product.

The current technological procedures of egg powder production are 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). Egg powder used in this sector caused an increase in competition and evolving expectations of the consumer as regard convenience and health, has continued to affect the trend of the market. Nowadays, consumers' are expecting more on improvements and developments in manufactured egg powder products (Asghar and Abbas, 2012).

2.8. Functional Property of Whole 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 uses for food materials as ingredients for the production of various food products (Daramola, 2018). The changes in the functionality of dried whole egg products are mainly caused by changes in protein state and properties.

Flowability is defined as the ability to flow freely, regularly, and constantly (Bhusari *et al*., 2014). It results from the size and shape characteristics of the individual particles, from their size distribution and the interaction between the particles themselves and their immediate environment (Pleass and Jothi, 2018). The flowability of a powder is a complex property that needs several characteristics to be taken into account. Compressibility; calculated from the aerated and packed bulk densities and cohesion of dried egg powder were the two properties chosen to achieve the flowability (Freeman, 2007). (Prasad *et al*., 2004) defined the following functional properties and highlighted their importance as follows: Emulsifying activity is the ability for a surfactant to form an emulsion under a 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.

Table 6; Functional Properties of Oven-dried Whole Egg powder and its components.

Functional Properties (%)	Whole Egg Powder	Egg Yolk Powder	Egg White Powder
Emulsification capacity (%)	55.00	74.00	17.77
Emulsification stability (%)	44.86	72.40	14.70
Emulsification reduction (%)	10.14	1.60	3.07
Foaming capacity (%)	40.00	38.50	28.08
Foaming stability (%)	59.29	28.08	78.30
Water absorption capacity (g)	1.60	0.50	1.80
Oil absorption capacity (g)	2.60	0.60	0.50
Coagulation temperature (^{0}C)	64.0	66.5	63.0
Solubility index (%)	92.00	88.00	96.00
Total solids (%)	93.26	96.12	95.88

Source: (Ndife et al., 2010)

The bulk density of a granular system results from the arrangement of the particles that depends on the size distribution and the cohesion forces of the particles. The application of tapping to a powder bed leads to the reduction of the aerated volume by the rearrangement of the constitutive particles (Amidon *et al*., 2009). It simulates the vibrations occurring during the conditioning, transport, and storage of the powders. The compressibility is related to the flowability of powder in that way: the higher the compressibility, the higher the tendency to compact of a powder bed and the worse the ability to flow (Šantl *et al*., 2011).

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. 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 to minimize these effects and to mitigate time of dry-heating.

2.9. Color of Whole Egg Powder

Color is one of the most important physical quality parameters that the consumer perceives and uses as a means to admit or castoff food. The color examination can be conceded out by color measuring instrument or by human (visual) inspection. The color test on the egg powder sample indicates the whiteness, which is considered a quality attribute as it affects the appearance of the final product. The darkness or whiteness of the powder is due to their feeding type principally. Higher the whole egg extractions rate, the darker the color of the egg powder, and vice versa. To carry out a more objective color analysis, color standards (color spaces and numerical values) are often used as reference material which is used to create, represent and visualize colors in two and three-dimensional space (Leon *et al*., 2006; Trusell *et al.*, 2005). The RGB (red, green, and blue), the CMYK (cyan, magenta, yellow, black), and the L*a*b*color space are the three main color spaces that are used to define the color.

According to (Yam and Papadakis, 2004), the L*a*b* model has the largest range encompassing all colors in the RGB and CMYK gamut. The L*a*b* values are often used in food research studies. The L*a*b* color space is an international standard for color measurement developed by the (Eclairage, 2007). The L*a*b* color consists of a luminance or lightness component (L* value, ranging from 0 to 100), a* component (from green to red), and the b* component (from blue to yellow) along with two chromatic components (ranging from -120 to +120). The L*a*b* color is device independent, providing consistent color regardless of the input or output device (Abebe *et al.*, 2015).

2.10. Applications of Egg Powder on Food and Beverage Industry

Egg powders are situated as the most convenient, safe, and economic formulas of egg products. They are castoff in most of the food industries for their nutritious value and their aromatic power (Miranda *et al*., 2015). However, some applications need specific technological properties of egg powders (Lechevalier *et al*., 2013). A whole egg is also used in meat and fish products for its emulsifying and binding properties (Singh *et al*., 2008).

Egg yolk is also considered a traditional ingredient for desserts such as cakes and ice creams. Proportions from 2 to 10 % of the ingredient combination give color and creaminess or limit the sugar crystallization in products developed from egg yolk; such as custard and pastry cream (Lechevalier *et al*., 2013). In dried pasta, the whole egg is nowadays limited to regional specialties to add color and texture; however, the egg white/yolk ratio can be modified: egg white increases pasta firmness, whereas egg yolk aids pasta blowing during cooking (Alamprese *et al*., 2009). Egg powders are sometimes used as cocktail ingredients in a cold drinks such as ‘advocaat’ in Belgium and The Netherlands. However, the consumption of egg powders in beverages is very personal and often reserved for specific products designed for protein supplementation or clinical use (Rao *et al*., 2012).

2.11. The Role of Egg Powder Production in Food and Nutrition Security

By definition, food security is existent, ‘when all people at all times have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life’ (FAO, 2008). A given food can be adequate if it gives satisfaction to the people's dietary needs regardless of their culture, gender, and occupations. As stated by Chauhan and Sharma, (2003) eggs are an adequate and complete food that can be consumed across gender, occupation, and culture.

Research has shown that, in rural communities, poultry farming for egg and meat production is exercised to use as food or for income generation and that eggs are relatively cheap compared to other nutritious foods (Moreki *et al*., 2010). Although eggs are a cheaper source of protein (Bunchasak and Kachana, 2009), their availability is inconsistent. For eggs to form a part of food security they should be available to every person at all times. Nowadays, the availability of egg was affected by low yields faced by small farmers in the rural areas (Tshikosi, 2009), Diseases and parasites during wet and dry seasons (Leta and Bekana, 2010), and lack of constant supplementary feeding (Molla, 2010; Okeno *et al*., 2012). As result eggs tend to be more available in hot wet seasons but the eggs during this period can deteriorate fast due to high humidity and high temperature (Leta and Bekana, 2010).

According to (FAO 2007) cited by (Mnyandu, 2014) food security stability of food availability and accessibility is, when adequate food is available and accessible 'at all times' meaning that food must always be available throughout the year when needed. Seasonal variations and perishability of eggs negatively affect the stable, supply making it impossible for them to be available and accessible at all times year-round (Mnyandu, 2014). Besides seasonal variations, other factors are attributed to the instability of egg supplies across the year; some of which are age, breed, feed climate, and body weight (Molla, 2010; Mutayoba *et al*., 2011). In winter, egg production tends to be lower than in summer (Watson, 2011). In summer when eggs are plenty, a significant proportion of them are lost through deterioration because farmers have little or no knowledge of proper egg handling, storage, and preservation (Mnyandu, 2014).

Therefore, egg powder as an egg preservation technique could address the above-mentioned challenges. The rural households can use egg powder in place of fresh egg because it has a longer shelf life, nutrient-dense and it is easy to store and transport (Rannou *et al*., 2013; Rao and Labuza, 2012). However, the acceptability of egg powder to rural households who are not familiar with it may be a challenge. In addition to this, the findings of (Mnyandu *et al*., 2014) indicated that consumers will not only consume the egg powder but also use it as a livelihood option intervention to create job opportunities for the unemployed youth.

2.12. Role of Egg on Mitigation of Prevalence of Malnutrition

The prevalence of undernutrition is very high in developing countries especially in children under five ages and women (Black *et al*., 2008). As WHO/UNICEF, (2014) report indicates that an estimated 162 million children below five years of age in developing countries are stunted and about 55 million, are wasted. Ethiopia is primarily an agrarian society, of which its economy relies heavily on rain-fed agriculture, employing 85% of the workforce and accounting for 45% of the national GDP (UNDP, 2014). Of major concern among children and adults are Vitamin A, protein, and iron deficiencies, which can be avoided by the consumption of poultry meat and eggs (Moreki *et al*., 2010). Protein is essential for both the 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 vital role in vision and immunity among other functions (Roy *et al*., 2012).

Malnutrition is defined as it's either under-nutrition (underweight, wasting, and stunting) or overnutrition (overweight and obesity) (Joosten and Hulst, 2008). Malnutrition results from a combination of problems associated with poor diet, ill-health, and inappropriate care. Early childhood nutritional insufficiencies lead to inadequate growth, that in turn impairs brain development, creates academic difficulties, and can lead to a lifetime of reduced earning capacity and an elevated risk of non-communicable diseases (Victora *et al*., 2008). According to the Central Statistical Agency and ICF International, 2011 cited by Alemu and Umeta, (2015) Ethiopia has one of the highest rates of undernutrition in Sub-Saharan Africa. Lack of nutritional diversity and micronutrient-dense food consumption and problematic infant and young child nurturing practices contribute to this.

Under-utilization of food products that are rich in protein is a major challenge for rural households in Sub-Saharan Africa (SSA) World Health Organization (UNICEF, 2009). As a result, the prevalence of Protein-Energy Malnutrition (PEM) is a major challenge in Sub-Saharan Africa (UNICEF, 2009). Protein-Energy malnutrition (PEM) is a form of undernutrition whereby there is an inadequate intake of energy and protein (Faber and Wenhold, 2007; Raynaud-Simon *et al*., 2011). Eggs seem to have the potential to mitigate the prevalence of PEM in rural areas because eggs are a good source of high-quality protein, vitamins, and minerals (Asgar and Abbas, 2012; Bunchasak and Kachana, 2009). Although eggs are essential for nutrition and health, they are highly perishable with a shelf life of up to 14 days when stored at room temperature *(Jirangrat et al*., 2010). Since they require a special preservation technique to extend their shelf-life and enhance easy storage.

2.13. Storage Conditions of Egg Powder

As a result of varying egg production patterns, there are periods where households do not have an adequate amount of eggs to use as a source of nutrition. The major practices of egg storage are at room temperature and in refrigerators. The quality of a dehydrated product depends not only on the drying methods but also on the storage condition. A study by (Jirangrat *et al*., 2010) shows that when stored at room temperature, an egg lasts for 14 days after which it becomes runny. In a refrigerator, eggs will last for 4 - 6 weeks, however, most rural households do not own these appliances, therefore, it requires a special preservation technique to extend their shelf-life and enhance easy storage.

As (Rao *et al*., 2012) determined that the influence of water activity (aw) on the storage quality of a commercial spray-dried hydrolyzed egg white powder and (Koç *et al*., 2011) also found a lower capacity of emulsion stabilization and impaired color for whole egg powder during storage. In addition to this (Rao *et al*., 2012) also reported that the color of the egg white changed after storing the sample at 45 °C for 1 month and numerous structural changes occurred at aw from 0.43 to 0.79 including agglomeration, stickiness, and collapse. The study of gelling and color of a dried egg by (Caboni *et al*., 2005) had shown a dramatic change in the color was found in HDEW during storage. However, the gelling property of the dried egg was formed due to the storage of the sample at a high temperature for a long period.

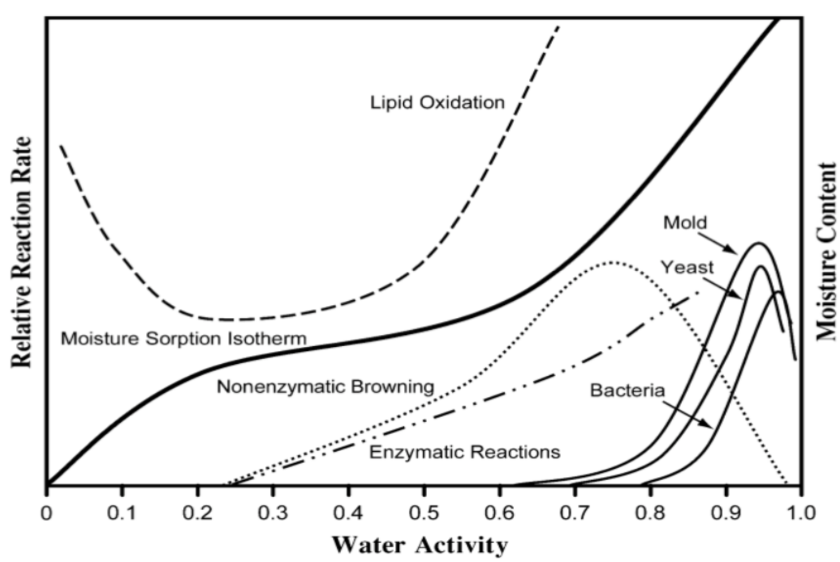


Figure 1: Food stability map as a function of water activity adapted from

Source: (Labuza, 1970)

Water activity is related to free energy in the concept of a thermodynamic concept. It's defined as at a given temperature, water activity is the ratio of the vapor pressure of food product (pw), in a system and the vapor pressure (pow), of pure liquid water at the same temperature" (Labuza, 1968; Reid, 2020).

2.14. Common Microorganism Survives on Egg Powder Products

Microbiological examination of more than 5,000 samples of spray-dried whole-egg powder (94 to 96 percent total solids content) manufactured in the United States has revealed a relatively high incidence of Salmonella contamination. According to (Gibbons and Moore, 1944) study conducted in Canada, Salmonella Spp. is a common pathogenic microorganism in spray-dried whole-egg powder. Because of the nature of the dehydration process, it would seem that the Salmonella organisms enter the processing system by way of the raw material.

Several investigators, including (Howard *et al*., 2012; Perry and Yousef, 2012) have observed that egg meats of clean shell eggs are generally sterile.Salmonella has been shown to survive at -20C for up to 16 weeks on pre-cooked chicken products (Dominguez and Schaffner, 2009) and such products have been identified as the vehicle of infection in large outbreaks of salmonellosis, including an outbreak in Spain in 2005 that sickened over 2000 people (the largest known outbreak of foodborne illness in that country) (Lenglet and Spain, 2005) and a 2012 outbreak in Finland in which 53 confirmed cases were attributed to cooked ''chicken cubes'' produced in China (Huusko *et al.*, 2017).

2.15. Shelf Stability of Egg Powder

Shelf-life is defined as "the time in which the food product will: remain safe, be certain to preserve desired sensory, chemical, physical, and microbiological characteristics, and comply with any label declaration of nutritional data when stored under the recommended conditions" (Kilcast and Subramaniam, 2000). According to shelf life rules, food can be divided into four categories: 1) Perishable (1-14 days at refrigerated temperature), 2) Extended refrigerated shelf life (60-90 days), 3) Semi perishable (≤ 6 months at room temperature), 4) Shelf-stable (≥ 6 months to 3 years).

Pasteurization is effective for reducing the risk of human infection from Salmonella in egg products (Latimer *et al*., 2008). Nonetheless, some Salmonella, especially heat resistant strains, have been isolated from pasteurized egg products in the United States (Gurtler *et al*., 2015). The observation that 1 (0.10%) of the pasteurized liquid whole egg samples and none of the pasteurized egg mix samples tested by AMS were positive for Salmonella is in line with data from FSIS, in which 41 (0.13%) of 30,696 samples of pasteurized liquid, frozen, and dried egg products collected from calendar years 2008 through 2017 were found positive for Salmonella as stated on Food Safety and Inspection Service, 2018) cited by (Johnson *et al*., 2019; Scott *et al*., 2020). Lipid hydroperoxide was proposed to be the indicator of irradiated egg powder based on a linear relationship between the formation of hydroperoxides and radiation dose below 4 kg, a sufficient dose to inactivate Salmonella in egg powder (Gasparovic *et al*., 2013).

2.16. Regulations Concerning Microbiological Safety of Foods

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

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) Mesophilic aerobic bacteria shall not exceed 20,000 colonies forming unit per gram or milliliter;

(d) Coliforms shall not exceed 500 per gram or milliliter of an egg product; and

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

3. Materials and Methods

3.1. Study Area and Raw Materials

The experiment was conducted at Addis Ababa University, Center for Food Sciences and Nutrition Laboratory, for analysis of mineral content, and Ethiopian Institute of Agricultural Research, Food Sciences, and Nutrition Research Directorate laboratories, physical characterestics, proximate composition, shelf stability study and organoleptic property (HAR, EIAR-HQ, and SNFR). Functional property of whole egg powders were carried out at DzARC. The experiment was done in triplicate both for the spray and oven drying to determined yield whole egg powder. Then, the whole egg powders produced were analysed for nutritional composition, sensory evaluation, major and trace-mineral contents, functional property and shelf stability. At the initial time (t_0) and at every month of the storage period, shelf life indicator parameters such as moisture content, water activity, pH, peroxide value, total aerobic mesophilic bacterial count, total coliform, and salmonella *spp.* were carried out for up to four months of the storage period. The whole egg powder packed in aluminum foil and plastic cups was stored under room temperature and 38 ^oC.

Chemicals and reagents used on this study were listed as shown below, and all the chemicals and reagents castoff were analytical grades. Chemicals ; sulphuric acid, hydrochloric acid, sodium hydroxide, acetic acid, nitric acid, sodium chloride, and reagents; plate count agar, phosphate buffer water, violate red bile agar, rapport vassiliadis soy peptone, xylose lysine deoxy cholate, analytical gared standards of reference minerals, and sunflower oil. All the chemicals and reagents were found from Ethiopian Institute of Agricultural Research, Addis Ababa University, Center for Food Science and Nutrition.

3.2. Experimental Design

A completely randomized design (CRD) with a factorial experiment with three replications was implemented. The influence of egg-type and drying methods on the physical characteristic, nutritional composition, mineral content, sensory evaluation, functional property, and color of the whole egg powder was studied. The nutritional contribution of the egg powder was also evaluated. The shelf-life stability of the whole egg powder: was also evaluated using the influence of eggtype (exotic and indigenous breed eggs), drying method (oven drying, and spray-drying). Storage materials (aluminum foil and plastic cups) and temperature (room temperature and at 38 $_oC$).

Experiment One: Production and Evaluation of Spray and Oven Dried WEP from Local and Exotic Eggs

3.3. Egg Sample Collection

One hundred fifty exotic breed eggs from the same breed types of a poultry research program, Debrezeit Agricultural Research Center, Ethiopian Institute of Agricultural Research, and 150 indigneous breed egg samples from private poultry farms of a specified breed were collected (i.e.purposive sampling method). The hen farming system were applied by an intensive farming system, and specified feeding system were imlimented. The egg samples were collected from debrezeite area which is located at eastern part of addis ababa, altitude of 1800 above sea level with an average temperature of 20 ^{o}C. Egg samples were packed in rectangular egg rack boxes and taken to the Food Sciences and Nutrition Laboratory of Ethiopian Institute of Agricultural Research and Reaction Laboratory of school of Chemical Enigneering, Addis Ababa University.

3.4. Egg Sample Preparation

The eggs were candled to confirm their freshness and cleaned by dusting, washing, and allowed to dry. Then, the eggs were selected and homogenized in size and weight via a digital balance. Following pre-selection and collection, the whole egg samples were kept at Holetta Agricultural Research, Ethiopian Institute of Agricultural Research. The eggs were then washed and dried using distled water. Then, each egg was crushed, homogenized (T25-digital, Germany), pasteurized using a water bath (YCW-012S, Taiwan) at 70 ^{o}C for 3 min, before oven and spray drying.

3.5. Drying of Whole Egg

3.5.1. Oven Drying

Oven drying was carried out according to the method described by Adams *et al*., (2005) with some modifications(pour thickness and time of drying). The cleaned, washed and dried eggs from local and exotic breeds were carfully deshelled. Then, 250 ml of whole egg liquid were poured in to backing oven plate and oven-dried at 44^{o}C for 4 hr (DHG-9123A Michel, England) and allowed to cool. The egg flakes were scooped, milled using coffee griender (FW 100, China) and then weighed via a digital balance (HR-300i, Japan). Finally, the egg powder were bagged in self-seal air-thight polyethylene bags and was stored at − 20°C until further analyses (Figure 2, 3 and 6).

Fresh good quality shell whole egg

↓

Dry cleaning and washing

↓

Deshelling

↓

Homognaization and pasturisation

↓

Pouring into trays

↓

Oven drying (44 ^{0}C for 4 hours)

↓

Cooled and scooped the flake

↓

Milling/sieving

↓

Egg powder with air-thight PE bag

↓

Stored at -20 oC

Figure 2: Flow diagram of whole egg processing into powder.

Source: (Ndife et al., 2010)

3.5.2. Spray Drying

Spray drying was carried out according to the method described by Koç *et al*., (2011). The local and exotic breed eggs being cleaned, washed and dried were carefully deshelled. The whole egg was homogenized and spray dried using a piolt-scale spray (Armfield FT 80, Agilents, USA) equipped with a rotary atomizer (Figure 4). During liquid whole egg drying using spray dryer, 500 ml of liquid whole egg were feed per batch, to avoied moisture adsorption during the drying process. The operational conditions of the spray dryer were inlet air temperature (*Ti*) of 180 °C, outlet air temperature (*To*) of 80 °C, atomization pressure (AP) of 1 bar, feed temperature of ∼10 °C, hot air flow rate of 1.54 m^3/min. The spray dried whole egg was milled, packed in self-seal polyethylene bags and stored under refrigerator until further analysis (Figure 6).

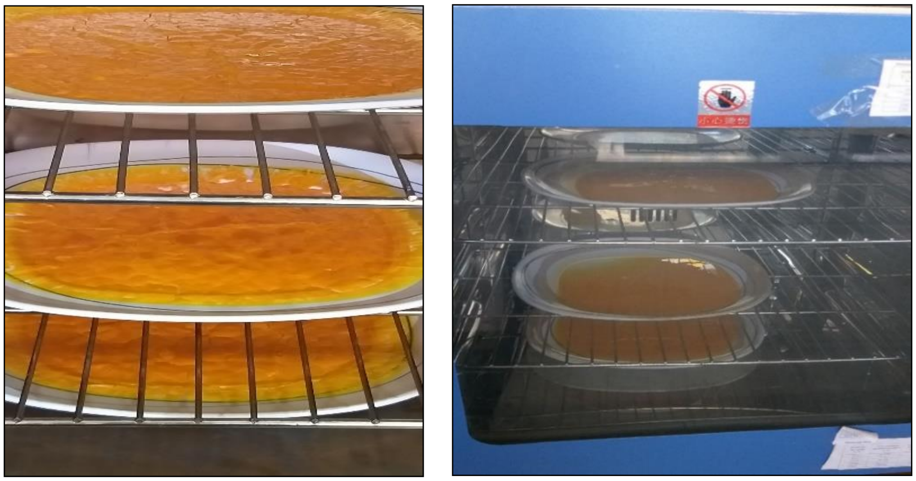


Figure 3: Whole egg drying for egg powder production using Vacuum Oven

Figure 4: Spray dryer used to make whole egg powder

3.6. Whole Egg Powder Yield

The percentage yield of the product from the raw material during whole egg powder processing was determined using the weight of the fresh egg, whole egg liquid, and whole egg powder (Daramola, 2018):

$$Flour\ yield = (\frac{weight\ of\ extracted\ egg\ powder\ g}{weight\ of\ whole\ egg\ used\ g} * 100 \qquad (1)$$

3.7. Physical Characteristics of Whole Egg Powder

3.7.1. Moisture Content

Moisture content was determined using the standard method of the AOAC 925:10 (AOAC, 2000a). 2 g of dried whole egg powder will be weighed, transferred to the hot-air electric oven (Model DHG-9123A Michel, England) set at 130°C for 1 hrs., cooled in desiccators for 30 min and weighed. The sample was dried again for 1 hour, cooled in a desiccator for 30 min and weighed until gained a constant weight. Finally, the moisture content of the sample was calculated as follows:

$$Moisture\ Content\ (\%) = \frac{w2-w3}{W2-w1} * 100 \qquad (2)$$

Where, W_1=weight of the empty container & cover; W_2=weight of the container, it's cover & the sample before drying; W_3=weight of the container, its cover & sample after drying or 1 hour, and then co oled to room temperature.

3.7.2. Water Activity

Water activity (aw) of the egg powders was measured according to the method described by Koç *et al*., (2011) with a water activity measurement device (Wert-Messer, Germany), with a ±0.001 sensitivity.

3.7.3. pH

The pH value of the reconstituted whole egg powder was measured with a digital pH meter (Type H1 98106, HANNA) by calibrating the pH meter using calibration buffers of pH 4.0, 7.0, and 9.2.

3.7.4. Aerated and Tapped Bulk Densities

The aerated bulk density of the egg powders was determined by measuring the weight of the powder and the corresponding volume. Approximately 20 g of powder sample was placed in a 100-mL graduated cylinder. The aerated bulk density was calculated by dividing the mass of the powder by the volume occupied in the cylinder. For the tapped density, the cylinder was tapped steadily and continuously on the surface by hand until there was no further change in volume; 100 tapping was determined to be enough in three parallel measurements (Jinapong *et al*., 2008). Finally, the bulk density and tapped density of the egg powder was calculated as follows:

$$Aerated\ bulk\ density\ \left(\frac{g}{ml}\right) = \frac{weight\ of\ sample\ g}{volume\ of\ sample\ occupied\ the\ space\ ml} \qquad (3)$$

$$Tapped\ bulk\ density\ \left(\frac{g}{ml}\right) = \frac{weight\ of\ sample\ g}{volume\ of\ sample\ after\ tapping\ ml} \qquad (4)$$

3.7.5. Flowability

The Flowability of the egg powders was evaluated according to the method described by (Carr, 1965) in terms of Carr index (CI) value. CI was calculated from the bulk and tapped densities of the powder as shown below:

$$Carr\ index = \frac{aerated\ bulk\ density - tapped\ bulk\ density}{tapped\ bulk\ density} * 100 \quad (5)$$

3.8. Proximate Composition of Whole Egg Powder

The egg obtained from the exotic and indigenous bread was subjected to determine its chemical composition. The biochemical analyses of the whole egg powder; fat content, protein content, ash content, crude fiber, were determined according to standard procedures AOAC, 2010 method of Horwitz and Latimer, (2010). The dietary carbohydrate was determined using percentage difference and gross energy was determined from protein, fat, and carbohydrate.

The nutritional quality of the egg and its components will be assessed using their proximate compositions as a guide. The proximate composition of the dried egg powder such as:

3.8.1. Ash Content Determination

The ash content was determined by the furnace method using a standard method of AOAC 923:03. 2010 (AOAC, 2000b). Two g of dried whole egg powder sample was weighed on a crucible and transfer to a muffle furnace, (Model, SX2-4-10GJ, Germany) set at 550 ^oC for 5hr, cooled in desiccators for 30 min, and weighed. Finally, the ash content of the sample was calculated as follows:

$$Total\ ash = \frac{M3 - M1}{M2 - M1} * 100 \quad (6)$$

Where M1=weight of crucible; M2=weight of fresh sample and crucible; M3=weight of crucible and ash,

3.8.2. Determination of Crude Protein

The protein content was determined using the Kjeldahl method as described on the standard method of AOAC 981:01. 2010 using (Kjeltec ^{TM} 8400, Sweden). 0.5 g of dried whole egg powder were weighed on a Tectar digestion tube placed on a Tectar rack, 10 ml of conc.H_2SO_4 and a mixture of catalyst (copper sulfate + potassium sulfate) were added, and the sample was digested on a digester block (Digestor 2520 Auto, FOSS, Sweden) at 420 ^oC for 1 hr. until a clear solution has appeared. Then the digestion tubes in the rack were transferred into a fume hood to cooled, 50 ml of dis.H_2O was added to avoid precipitation of sulfate in the solution, the clear solution was distilled and titrated with 0.1 N HCl. Finally, the protein content of the sample was calculated as follows

$$Nitrogene\ content\ (\%) = \frac{(VHCl - Vblack) in\ L * N\ HCl\ * 14 * 100}{\mathrm{WO}} \quad (7)$$

Where: V=volume of HCl in L consumed to the endpoint of the titration; N=normality of HCl; W_O*=sample weight on dry matter basis; 14=the molecular weight of nitrogen*

$$Protein\ content\ (\%) = 6.25 * \%N \quad (8)$$

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).

3.8.3. Determination of Crude Fat

The fat content of the sample was determined using the Soxtec method (Soxtec ™ 8000, Sweden) of the official AOAC 991:36. 2010. A clean aluminum cup with a boiling chip was dried for 1 hr. in a drying oven at 105^{o}C and cooled to a desiccator for 30 min. The dried cup was weighed and cover the bottom of an extraction thimble with a layer of fat-free cotton. 2 g of dried whole egg powder was weighed and cover with a layer of free fat cotton, the thimble and aluminum cup was put on an extraction chamber and 60 ml of n-Hexane were added, and the sample was extracted for 1hr and 5 min (Boiling time 25 min, Rinsing time 30 min and recovery time of 10 min). Then the extraction cylinder was disconnected and put on a drying oven set at 105 ^{o}C for 30 min, cooled in a desiccator for 30 min, the extraction cylinder which contains the fat were weighed. Finally, the fat content of the sample was calculated as follows:

$$Fant\ Content\ (\%) = \frac{(W2 - W1)}{W} * 100 \quad (9)$$

Where: W1=weight of the extraction cylinder; W2=weight of the extraction flask plus the dried crude fat (g); W=weight of the sample (g)

3.8.4. Determination of Crud Fiber

The fiber content of the sample was determined using a gravimetrical method of the official method of AOAC 945.38, 2010 using (Fiber Tec ™ 8000, Sweden) (Kleintop *et al*., 2013). 2 g of dried egg powder sample was weighed into a fiber digester crucible, the weight of the empty crucible were also recorded. The sample was digested by 1.25 % H2SO4 followed by digestion with 1.25 % of NaOH. At each digestion step with the acid and the alkaline, the sample was washed with distilled water three times. After digestion was completed the sample was dried in an air-ventilated oven at 130 oC for 1 hr. and the weight was recorded as W2. Then the sample was ashed on a muffle furnace at 550 oC for 4 hrs. and weighed (W3). Finally, the fat content of the sample was calculated as follows:

$$Fiber\ Content\ (\%) = \left(\frac{W2-W3}{W1}\right) * 100 \quad (10)$$

Where, W1=weight of a sample (g); W2=weight of crucible and sample after drying (g); W3=weight of crucible and sample after ashing (g)

3.8.5. Utilizable Carbohydrates Calculation

Carbohydrate content was determined by subtracting the sum of the percentages of moisture, ash, protein, and lipid content from 100 (Al-Farsi *et al*., 2007).

$$Carbohydrate\ (\%) = 100 - (MC + Ash + protein + Fat + Crude\ Fiber) \quad (11)$$

3.8.6. Energy Calculation (Kcal/100g)

The energy was obtained based on the values of crude protein, crude fat, and total carbohydrate which were multiplied with factors of 4, 9, and 4 respectively, i.e., was calculated in kilocaloriesper100g of the sample as reported by Osuagwu, (2008) and shown below.

$$Energy\ \left(\frac{kcal}{100g}\right) = (4 * g\ protein) + (4 * g\ carbohydrate) + (9 * g\ Fat) \quad (12)$$

3.9. Mineral Content of Whole Egg Powder

The mineral analysis of whole egg powder such as Calcium (442.7 nm), Potassium (776.5 nm), Magnesium (285.2 nm), Sodium (589.0 nm), Iron (248.3 nm), Zinc (213.9 nm), copper (324.8 nm), and manganese (279.5 nm) was carried out using the official method of AOAC (2010), code 923.03 (model AA 4200 ,Agilent, USA) flame atomic absorption spectrophotometer equipped with Spectra AA (Agilent, Australia) hollow cathode lamps as the radiation source (Ieggli *et al*., 2010). Acetylene–air flame was used as an energy source; the gas flow rates and the burner height were adjusted to obtain the maximum absorbance signal for each element. However, phosphorus was determined using UV-Visible spectrophotometer at a wavelength of 690 nm. Different standared concentrations for each element were used for developuing a caliberation curve see annex 20.

Briefly, 1 g of egg powder was ashed using muffle furnace (Carbolite, Aston Lane, Hope, Sheffield s30 2RR, England) at 550 ^{0}C for 4 hrs. The ash was dissolved in 5 ml of 6 M HCl. Subsequently, 15 ml of 3 M HCl was added and heated until the solution boils. The digested sample was cooled, filtered, and adjusted to the required volume using demineralized water.

$$Mineral\ Content\left(\frac{mg}{100g}\right) = \frac{(R-b)*V*df}{10*Swt} \quad (13)$$

Where: R=reading (concentration of the mineral in ppm); B=blank sample (without egg powder); V=total volume; Df=dilution factor; S=sample weight of whole egg powder 1g

$$Phosphors(\%) = \frac{(R-b)*V*df}{S*Aliq} \quad (14)$$

Where: R=reading (absorbance of phosphors in ppm); B=blank sample (without egg powder); V=total volume; Df=dilution factor; S=sample weight of whole egg powder 1g; Aliq=aliquot of a sample taken for the reading

3.10. Color

The colors of the whole egg powder samples were determined using a colorimeter as described by Rao *et al*., (2012), to measure the CIE color parameters (L*, a*, and b*). Before analysis, the meter was calibrated with the white CR-221 calibration plate (Minolta) and using color standards. The color was measured using an absolute measuring mode following the manufacturer's instruction and calculated automatically using the CIE 1976 L⁄ a⁄ b⁄ color space system. In this system, the coordinate L* indicates lightness on a scale from 0 (black) to 100 (white); a* is + (red) or - (green) and b* is + (yellow) or - (blue). The total color differences (ΔE*) were obtained using equation 15, where ΔL*, Δa*, and Δb* define the color differences in the samples before and after storage under the various storage conditions. The measurement of each sample was done in triplicate.

$$E = \sqrt{(L2\ +\ a\,2\ +\ b\,2)} \quad (15)$$

3.11. Determination of Functional Properties of Whole Egg Powder

Functional properties of foods determine the application and use of such food materials as ingredients for the production of various food products (Yeshajahu, 1991).

3.11.1. Emulsification Capacity

Each egg powder sample was subjected to emulsification capacity determination as described by (Onwuka, 2005). Two grams of powder were blended with 25 mL distilled water at 28±2°C, for the 30s, at 1,600 rpm. Then 25 mL groundnut vegetable oil was gradually added, blended for another 30s, then transferred into a centrifuge tube (Model Tx 425) and centrifuged at 1,600 rpm for 5 mins. The height of the whole solution in a tube (Amm) and height of the emulsified layer, with no separation (B mm), was taken. Finally, the emulsification capacity of the WEP was calculated as follows:

$$Emulsification\ capacity(\%) = \left(\frac{Bmm}{Amm}\right) * 100 \qquad (16)$$

Triplicate determinations for each sample will be made and the mean values were recorded.

3.11.2. Water Absorption Capacity

Water absorption or hydration capacity of egg powder was determined as described by (Onwuka, 2005). One gram egg powder was weighed into a conical graduated centrifuge tube, and 10 mL distilled water was added, mixed and, centrifuged (in centrifuge tube Model Tx425 made in England) at 5,000 rpm for 30 mins. Then, it was allowed to stand for 30 mins. The free water volume was recorded and the weights of the tube before mixing with water and after decanting were recorded. Finally, the water absorption capacity of the WEP was calculated as follows:

$$WAC\left(\frac{ml}{g}\right) = \left(\frac{V}{W2-W1}\right) \qquad (17)$$

Where: WAC=water absorption capacity (ml/g); V=volume of water absorbed (ml) ; W2=weight of tube and WEP after decanting (g); W1=weight of tube and WEP before mixing with water (g)

(Note: density of distilled water=1g/mL); Water absorption capacity is expressed as mL water/g powder; Triplicate measurements were made for each powder and the average recorded.

3.11.3. Oil Absorption Capacity

The oil absorption capacity of egg powder was determined by the centrifugation method described by Onwuka, (2005). One gram of egg powder was mixed with 10 ml of sunflower oil in 50 mL centrifuge tubes. The dispersions were occasionally vortexed while they are held at room temperature for 30 min, followed by centrifugation for 30 min at 3000 rpm (Thermo Fisher Scientific, Germany). The supernatant was removed and weighed and results were expressed as a milliliter of oil absorbed per gram of egg powder.

$$OAC\left(\frac{ml}{g}\right) = \left(\frac{V}{W2-W1}\right) \qquad (18)$$

Where: OAC=oil absorption capacity (ml/g); V=volume of oil absorbed (ml); W2=weight of tube and WEP after decanting (g); W1=weight of tube and WEP before mixing with oil (g)

3.11.4. Foaming Capacity

The foaming capacity of whole egg powder samples was determined according to the method described by (Stadelman, 1995) with some modifications. One gram whole egg powder Sample was blended as applicable with 50 mL distilled water in a warring blender, (England, Model WB-1), and the suspension was whipped at 1,600 rpm for 5 minutes. The mixture was then poured into a 100 mL measuring cylinder and volume were recorded. Finally, the water absorption capacity of the WEP was calculated as follows:

$$Foaming\ Capacity(\%) = \frac{V1-V2}{V2} * 100 \quad (19)$$

Where: V1=volume after whipping; V2=volume before whipping

3.11.5. Soluble Protein Content

Samples of egg powder were prepared according to the procedure illustrated by Franke and Kießling, (2002). Two grams of egg powder was reconstituted with 0.3 M NaCl solution to a protein content of 0.7 mg/ml and adjusted to 100 mL and a pH value of 7.0 (adjusted with 1 N HCl or 1 N NaOH). After stirring for 2 h at room temperature, the suspension was immediately centrifuged for 20 min at 12000 rpm for the sedimentation of insoluble proteins. Finally, the soluble protein content was determined using the Kjeldahl method as described on the standard method of AOAC 981:10. 2010 (McGill, 1981).

$$Protein\ Solubility(\%) = (\frac{total\ amount\ of\ protein\ insupernatant)}{(totalamount\ of\ protein\ in\ egg\ powder)} * 100 \quad (20)$$

3.12. Contribution of WEP to Nutrient Intake

The potential contribution of the WEP as an ingredient for complementary food and, or as an alternative protein source in ready to use therapeutic food (RUTF) with the potential to fully or partly replace milk powder was evaluated in percentage of the requiernment per meal foe an egg (one egg ~ ti 12 g powder) (Lutter and Dewey, 2003). The compositions in the egg powder were evaluated against protein recommendations in RUTF (WHO and FAO, 2019).

3.13. Sensory Evaluation of Whole Egg Powder

3.13.1. Preparation of WEP and WEP-Based Product

The WEP was presented on a small size ceramic dish for sensory attributes test including appearance, color, odor, texture, and overall acceptability. For the taste attribute, Shiro wet (legume based Ethiopian stew) was prepared incorporating WEP as ingrdient togethaer with field pea, in which all the ingrdients used for recipe preparation were measured. The whole egg powder prepared using the oven and spray drying were added to the shiro wet, shiro wet without WEP was used as a control. Briefly, the shiro wet recipe was prepared using the ingredient composition of 22 g field pea powder (shiro), two tea spoon (appr. 14 g) of egg powder, 250 mL water and other usual flavour enhance components; salt, oil. The cooking temperature was on the range of 90-110 ^{o}C.The egg powder was added 4-5 min befor the shiro cooking was enough. Panelists rated the recipe either it gives up any off-flavor (taste) in comparison with the control shiro wet.

3.13.2. Sample Coding, Serving Order, and Sensory Evaluation Set-Up

Samples of whole egg powder, whole egg powder recipe Shiro wet, and Shiro wet without whole egg powder as control were coded with three-digit numbers obtained from a Table of Random Numbers. The samples were tested in a randomized order from left to right. Randomization of the serving order of the whole egg powder and the whole egg powder recipe samples was done using a Table of Random Permutations of Nine. Before and after tasting each product, the panelists will be requested to gargle.

3.13.3. Panelists

The sensory panelists were composed of sixteen members of the young-adult women and men researchers and staff members of the Ethiopian Institute of Agricultural Research (HARC, MARC, and DzARC). The panelists were selected based on the test type which is for the rating acceptance tests, semi-trained researchers of food sciences and nutrition M.Sc. holders were used. The study for the sensory attribute of the egg powder was done at the Ethiopian Institute of Agricultural Research, Food Sciences, and Nutrition Research Laboratory. The panelists were not addicted to any drug and not at any medication. According to Mnyandu *et al*., (2014). The panelists were made to sit in a back to back position to avoid the interaction. The sensory evaluation score sheet was in a 7-point pictorial hedonic scale ranged from 1= extremely dislike, 2=moderately dislike, 3=slightly dislike, 4=nither like nor dislike, 5=slightly like, 6=moderately like, and 7= extremely like. The panelists were asked to rate the acceptability of each sensory attribute of the WEP by marking an ‘X’ on the face which best described their sensory perception.

Experiment Two: Shelf Stability of Whole Egg Powder during the Storage Period

3.14. Shelf Stability Study of Whole Egg Powder

In this study, the shelf-stability of WEP testing was conducted starting from the initial time (t_0) up to four months of duration period. The shelf life evaluation was conducted under two storage temperature (room temperature and and tropical temperature) conditions which are at two storage temperatures (temperate and tropical temperature) using two storage materials (plastic cup and aluminum foil), and the shelf life indicator parameters were done every month.

The shelf stability indicator parameters were analysed on monthly basis. In fact sampling plan depends on the shelf life of the product. The shelf-life evaluation was conducted as a kinetic reaction approach to predict the deterioration of predictive parameters as a function of time (Corradini and Peleg, 2007; Labuza and TP, 1982).

Figure 5: Whole egg powder packed in plastic cup and almunium foil

3.14.1. Determination of Moisture Content

Moisture content was determined using the standard method of the AOAC 925:10. (2010) (AOAC, 2000a). Two g of dried whole egg powder will be weighed, transferred to the hot-air electric oven (Model J. 02707 Michel, England) set at 130°C for 1 hrs, cooled in desiccators for 30 min, and weighed. The sample was dried again for 1 hour, cooled in a desiccator for 30 min and weighed until gained a constant weight. Finally, the moisture content of the sample was calculated as follows:

$$Moisture\ Content\ (\%) = \frac{w2-w3}{W2-w1} * 100 \qquad (21)$$

Where: W1=weight of empty containers and cover; W2=weight of containers, its cover and sample befor drying; W3=weight of containers, its cover and sample after drying

3.14.2. Determination of pH

The pH value of dried whole egg powder will be measured with a digital pH meter (Type H1 98106, HANNA) by calibrating the pH meter using calibration buffers of pH 4.0, 7.0, and 9.2.

3.14.3. Determination of Water Activity

The water activity (aw) values of egg powders will be measured according to the method described by Koç *et al*., (2011) with a water activity measurement device (Wert-Messer, Germany), with a ±0.001 sensitivity.

3.14.4. Total Aerobic Mesophilic Bacterial Count

Enumeration of TAMB in WEP was done by pour method according to standard procedures recommended by FDA, (2001). Using separate sterile pipets, the whole egg powder solution was prepared as a decimal dilution of 10^{-2}, 10^{-3}, 10^{-4}, and others as appropriate and homogenate by transferring 1 ml of the previous dilution to 9 ml of diluent. One ml of each dilution was pipetted into separate, duplicate, appropriately marked Petri dishes. The dilution bottle was re-shacked 25 times in a 30 cm arc within 7 sec until it is pipetted into the petri dish.15 ml plate count agar was added (cooled to 45 ± 1°C) to each plate within 15 min of original dilution. After that, immediately sample dilutions and agar medium were mixed thoroughly and uniformly by different rotation and back-and-forth motion of plates on a flat level surface. Agar was solidified and solidified Petri dishes were inverted and incubated promptly for 48 ± 2 h at 35°C. Plates have not stacked when pouring agar or when agar is solidifying. Finally, all aerobic plate counts were computed and reported from duplicate plates FDA, (2001).

3.14.5. Total Coliform Count

Enumeration of total coliform in WEP was done by pour method according to standard procedures recommended by FDA, (2001). Accordingly,10 g whole egg powder was weighed into a sterile high-speed blender jar.450 ml Butterfield's phosphate buffered dilution water was added and blend for 2 min. Then, one ml of the initial dilution was taken and added into a sterile test tube having 9 ml of peptone water. After mixing, the sample is serially diluted up to 10^{-5} and 1 ml of inoculum was taken from all dilutions and mixed thoroughly with molten 15–20 ml Violet Red Bile Agar. After thoroughly mixing, the plated samples were allowed to solidify and then incubated at 37 °C for 24 hours. Typical dark red colonies are considered as coliform colonies and counted by the digital colony counter. Approximately, the plate contained the number of colonies between 30 and

300 was selected among the dilutions and finally, the CFU/ml or g of the total coliform count in the samples was done using the formula given by FDA, (2001).

3.14.6. Salmonella

Isolation of salmonella *spp.*. from whole egg powder was based on the recommendation by International Standard Organization and Unites States of Food and Drug Authority (FDA, 2001) method with some modification (omission of trionate broth). Aseptically 25 g whole egg powder sample was taken by sterile measuring pipette and weighing boot respectively. Isolation of salmonella *spp.*. involved three basic stages. The first stage was pre-enrichment of Salmonella *spp.*. in samples, by mixing 25ml/gram in 225 ml of sterilized buffer peptone water and allowed to incubate for 24 hours at 37℃. The second stage was an enrichment of salmonella *spp.*. in which 0.1ml of pre-enriched culture was transferred into 10 ml sterilized selective media broth, Rapport Vassiliadis soy peptone (RVs), and incubated at 41.5±0.5℃ for 18-24hours. The final stage was culturing of Salmonella *spp*.. through a loop of the samples was taken from selective media and streaked onto xylose Lysine Deoxycholate (XLD) agar plates and further incubated at 37℃ for 24-48 hours. The presumptive of Salmonella *spp*. colonies on XLD agar which was a pink colony with or without black center or glossy black centers were selected and sub-cultured on Brain Heart Infusion (BHI) agar. For the confirmation of Salmonella *spp*.. a series of biochemical tests, like gram staining, triple sugar agar, Urea, Simon Citrate, motility test, and Carbohydrate utilization tests.

3.15. Statistical Analysis

The nutritional composition, functional property, mineral content, and organoleptic property data collected from whole egg powders were subjected to analysis of variance (two way ANOVA) by using SPSS software version 22.0. Student's independent t-test (SPSS version 22.0 for Windows, SPSS Inc. Illinois, USA) was carried out to determine the level of significance between means of triplicate measurements. Shelf life data collected from the initial time (t_0) up to four months of storage period were also carried out to determine the level of significance between means. All analyses were conducted in triplicate and the results were expressed as mean ± standard error of the mean and significant differences were defined at $p < 0.05$.

4. Results and Discussion

In this study the impact of egg types (exotic and local breeds) and drying methods (oven and spray drying) on the physico-chemical characteristics of WEP were compared. The investigated physicochemical characteristic include yield, nutritional composition, functional property, mineral content, and sensory attributes. Furthermore, the shelf-life stability of WEP in terms of its shelf life indicator parameters including; moisture content, pH value, peroxide value, water activity, microbial load (TAMB, Total Coliforms, and Salmonella) were evaluated. The shelf life study was conducted using two storage temperatures (room temperature and (~38 ^{o}C)) and using two packeging materials (plastic cup and aluminum foil).

4.1. Yield

The yield of WEP produced after drying of liquid whole egg to WEP has been shown (Figure 6). Eggs differ in size have a different eggshell, and egg liquid. As a result, they are differ for their yiel of WEP.

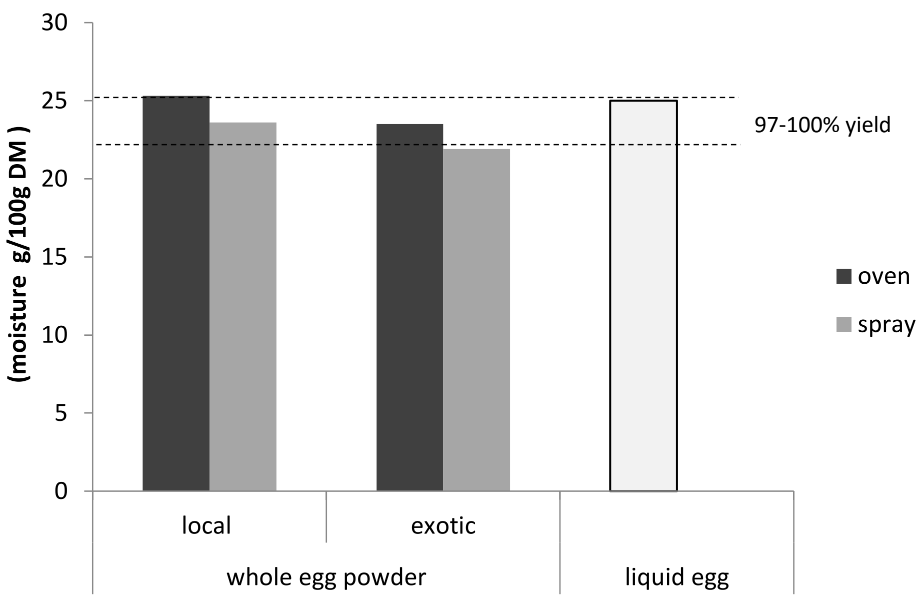


Figure 6: Yield (g/100g) of whole egg powder obtained from spray- and oven-drying of eggs from local and exotic chicken breeds (*DM: dry matter)*

The average weight of exotic and local breed whole eggs used for this study was 44.45 g and 43.96 g respectively. According to the Domestic Animal Diversity Information System reported by Wei *et al*., (2019) the average weight of a Kampung chicken egg was 42 g whereas, the Malaysian

Department of Veterinary Services (Wei *et al*., 2019), stated that the average egg weight was 65 g. Those findings have been shown that, the average weight of chicken eggs was varying for different types of hens.

The weight of WEP obtained relative to the original weight (liquid egg) was 22-25 % (Figure 6). Considering an average moisture content of liquid egg being ~75%, this suggests that the yield was > 97%. The WEP yield for exotic and local breed eggs produced using oven drying was 23.5 and 25.3 %, while the WEP yield produced using spray drying was 21.9 and 23.6 %. So, according to this study result, the WEP yield among egg types have significantly different ($P < 0.05$) for both drying methods. In most of the previous study by different scholars, the yield of the WEP has not been reported. As Ayadi *et al*., (2008) and Wei *et al*., (2019) previously reported, the yield of egg yolk powder from liquid egg yolk was 43.48%, this higher yield of egg yolk powder as compared to the WEP is due to the water content of an egg were higher in the egg white portion relative to the egg yolk.

The same inclination as in egg types was observed (Figure 6) for drying methods. The WEP yield mean values were significantly different $P < 0.05$. The average yield of WEP produced by oven drying for exotic and local eggs (23.5, 25.3 %), have reflected higher than the spray-dried exotic and local breed eggs with a mean value of 21.9 and 23.6 %. The egg powder yield found from the present study favorably comparable with the yield percentage reported by (Abdullah, 2008) oven-dried (21.90), and (22.4%) oven-dried and (26.7%) spray-dried by (Daramola, 2018).

The high yield of the powder relative to the liquid egg (> 97%), complemented with economies made in the transportation costs related to the removal of water that accounts for 75% of the egg's weight, and the requirement of lesser space for storage of the dried egg can contribute to making eggs more affordable. This, in the long-run, can increase demand and provide incentives for increased egg production, as low demand and high transaction costs are part of the reasons why supply is low in low-income countries (Morris *et al*., 2018). However, this warrants detailed cost-benefit analyses.

4.2. Physical characteristics of whole egg powder

Physical characterization of whole egg powder such as moisture content, pH, water activity, bulk property, and flowability has been reported and the change in its moisture content, water activity, and oxidation value (peroxide value) of the whole egg powder during storage was also presented in the shelf stability study section.

4.2.1. Moisture content and water activity

Whole egg powder with higher moisture content errands the growth of mold and insects, which can cause safety and quality deterioration during storage. As a result, WEP and its products with low moisture content are more stable during storage and the results were presented (Table 7). The moisture content of WEP for both drying methods was obtained < 5%. Spray drying gives a lower moisture content than oven drying. Egg powder obtained from eggs of exotic breeds had slightly higher moisture content than the local ones, irrespective of the drying procedure ($P < 0.05$).

The moisture content is significantly different between exotic and local breeds of WEP ($p < 0.05$). The mean value of the moisture content for the local and exotic breed WEP produced by oven drying was found to be 3.63 and 4.25 % wheras for spray drying was 2.56 and 3.39%. Moisture levels of 3–4% are generally recommended for egg powder (Galet *et al*., 2010b) that is faithfully reliable with our findings.

WEP deterioration is linearly correlated with moisture content. It is proved that the permeable moisture content of different egg powder products is < 5% at ambient storage condition. The moisture content obtained from both drying methods ranged from 2.56 - 4.25 %, and the result of this study was in line with the finding of 4.9 % as reported by (Vaclavik *et al*., 2008). As shown (Table 7), all egg powders have a solid mater content > 95 g/100. The solid matter contents of egg powders were in harmony with the criteria of the Department of Agriculture database. Like in egg types, there is also a significant difference between the moisture content of the drying treatments statistically at $P < 0.05$.

All the egg powders had a low water activity (0.44-0.49) and an alkaline pH (7.46-8.62) irrespective of the egg varieties. According to the study results (Table 7**)**, no significant variation of water activity between local and exotic breeds was observed ($p<0.05$). The water activity of local breed WEP for both drying was found to be 0.47, 0.44, whereas exotic breed WEP is 0.49 and 0.46. As per different works of literature mentioned that, the water activities were in the accepted range having 0.4-0.5 in their initial production stage. Normally water activity needs to be low enough to inactivate enzymatic reactions, mallard reaction, and survival of pathogenic microbial.

Table 7; Physical characteristics of whole egg powder produced from Ethiopian local and exotic egg varieties using oven and spray drying

Whole egg powder		
	Local	**Exotic**
Moisture Content (g/100g)		
Oven	3.63 ± 0.0^{aB}	4.25 ± 0.1^{aA}
Spray	2.56 ± 0.1^{bB}	3.39 ± 0.0^{bA}
Water activity (a_w)		
Oven	0.47 ± 0.0^{aA}	0.49 ± 0.0^{aA}
Spray	0.44 ± 0.0^{aA}	0.46 ± 0.0^{aA}
pH		
Oven	7.46 ± 0.0^{aB}	8.62 ± 0.0^{aA}
Spray	7.76 ± 0.0^{aB}	8.52 ± 0.0^{aA}
Aerated bulk density (kg/m^3)		
Oven	501.9 ± 5.3^{aA}	500.1 ± 0.1^{aA}
Spray	333.5 ± 0.1^{bA}	312.6 ± 0.1^{bB}
Tapped bulk density (kg/m^3)		
Oven	632.0 ± 11.6^{aB}	666.8 ± 0.2^{aA}
Spray	508.8 ± 7.5^{bB}	555.8 ± 0.1^{bA}
Flowability (%)		
Oven	20.6 ± 0.7^{bB}	25.0 ± 0.0^{bA}
Spray	34.4 ± 1.0^{aB}	43.7 ± 0.0^{aA}

Values are given as mean ± SE (n=3). The different lowercase letters in the same column and different capital letters in the same row within the same parameter denote a significant difference ($P < 0.05$) using the student's independent t-test. Where; BD-Bulk Density; TD-Tapped Density

There was also no significant difference between oven and spray driers for water activity at $P < 0.05$. As the literatures mentioned the water activity was in the accepted range for drying methods having since the mean ranged from 0.4-0.5 similar to egg-type variation. The water activity of oven-dried WEP for local and exotic breed eggs slightly higer as compared to the spray-dried WEP. According to (Caboni *et al*., 2005), low levels of water activity (0.32–.35) safeguard WEP alongside the Maillard reaction, even though this reaction is commenced during spray-drying (Rao *et al*., 2012). It is generally accepted that the water activity of WEP should be 0.40 and thus moisture content below 5% (Stadelman *et al*., 2017) to ensure the stability of dried products. At such low moisture and water activity, the powders are less susceptible to microbial growth (Labuza and Rahman, 2007).

4.2.2. The pH of whole egg powder

The pH value of WEP obtained from this study is ranged from 7.46 – 8.62. The pH value WEP for local and exotic breed eggs produced by oven drying was 7.46 and 8.62, whereas for the spray-dried eggs were 7.76 and 8.52 respectively. According to the result shown (Table 7), there was a significant difference between the pH values of egg types at $P < 0.05$. however, Stastical significant difference was not observed for pH value of WEP between drying methods. Exotic breed WEP has shown higher pH value as compared to the local breed whole egg powder for both oven and spray dryer. The higher pH value of exotic breed WEP as compared to local breeds might be due to the protein composition and moisture content, even though there are no previously conducted works on those local breed WEP. In addition to this, (Sharif *et al*., 2018) reported that the pH variation mainly exists due to the feeding type variation in which a high amount of phosphors makes the egg portion more acidic.

4.2.3. Bulk property of whole egg powder

The bulk properties of WEP are highly dependent on particle size and its distribution (Barbosa-Cánovas *et al*., 2005), and it is very important in determining packaging requirement and material handling (Peter-Ikechukwu *et al*., 2019). Higher bulk density is desirable in that it offers a greater packaging advantage as a greater amount of flour may be packed within a constant volume (Isah *et al*., 2013). The aerated and tapped bulk densities are thus relevant properties to envisage the conditioning and storage volumes of the powders. Higher bulk property is desirable for greater ease of dispensability and reduction of paste thickness (Mingle *et al*., 2017).

Aerated bulk density (kg/m^3) of WEP is the density measured without the influence of any compression. The result of the present study was recorded as aerated bulk densities of WEP for egg-type variation ranged from 312.6 - 501.9 kg/m^3. The aerated bulk density of WEP for the local and exotic breed eggs by oven drying was 501.9 and 500.1 mean while the spray drying WEP which was 333.5 and 312.6. According to the result shown (Table 7), there was no significant difference between aerated bulk density mean values of egg types statistically at $P < 0.05$ for the oven-dried WEP. Nevertheless, for the spray-dried product, the aerated bulk density was significantly higher in the local breed eggs, the reverse was true for tapped bulk density ($P < 0.05$).

On the other hand, as mentioned (Table 7) there was a statistically significant difference between oven and spray drying ($p < 0.05$). The bulk density was lower in the spray-dried than the oven-dried egg powders for both local and exotic egg types. For instance, the study of (Koç *et al.*, 2011) reflected that the bulk densities of spray-dried WE powder were in the range of 298–340 kg/m^3 which was in a similar trend with the current study. The higher moisture content of the WEP resulted in a lower aerated bulk density, but the reverse was true for tapped bulk density.

Tapped bulk density (kg/m^3) of WEP is the density measured with the influence of compression. The tapped bulk density of WEP throughout the egg types ranged from 508.8 – 666.8 kg/m^3 both for the oven and spray drying. The exotic breed WEP reflected higher tapped bulk density than local breed WEP. Starting from this point of view tapped bulk density mean values were significantly different among egg types at $P < 0.05$. Accordingly, (Schuck *et al.*, 2012) finding stated that the tapped bulk density of egg powders is close to the value of 508 kg m^3.

The same trend as in egg types, The drying variation for the tapped bulk density mean values were significantly different at $P < 0.05$. Oven-dried WEP reflected higher tapped bulk density than spray dried for both the local and exotic egg types. Tapped bulk density produced by the oven and spray drying of local breed WEP was 632.0 and 508.8 kg/m3 as compared to the exotic breed WEP which is 666.8 and 555.8 kg/m^3 respectively.

4.2.4. Flowability of whole egg powder

The flowability of WEP was determined using the aerated and tapped bulk density. The flowability of WEP for this work varried from 20.6 (local, oven-dried) to 43.7 (exotic, spray-dried). Although spray drying is the preferred method for processing WEP with better flowability as confirmed by our findings, the results from oven-drying was also could be promising in the absence of advanced technologies, oven-drying can be an alternative (Rannou *et al.*, 2015).

Depending on the finding from the present study, the flowability of the WEP means value was significantly different among egg types at $P < 0.05$ statistically. The flowability of local and exotic breed WEP produced by oven drying was 20.6 and 25.0 % while the spray-dried was being 34.4

and 43.7 %. Both for the oven and spray drying flowability were higher for exotic breed whole egg powders.

As a similar manner with egg type, significant differnces were observed for both drying methods between eag types. The highest flowability was observed for spray drying of exotic breed eggs.

4.3. Proximate Composition of Whole Egg Powder

Proximate composition such as moisture, ash, protein, fat and fiber were analized in this experiment, and theire mean values presented (Table 8). The moisture content of the food item is a needle of product stability. WEP with higher moisture content favors Maillard reaction, lipid oxidation, enzymatic activity, and enhancing of microbial loads, which can cause safety and quality deterioration during storage. Hence, WEP and its products with low moisture content are more stable during storage. The moisture content was discussed (Table 7) on the physical characteristics section.

4.3.1. Crude Protein

The high protein content of egg makes it an excellent likely protein source for food industry applications. The protein content obtained in this study ranged between 44 to 48 g/100g and was higher in the egg powder obtained from the exotic than local breeds. Bestowing to statistical independent t-test mean comparison at $P < 0.05$, there was a significant difference between the protein content of egg types. The protein content of oven-dried local and exotic breed WEP was 45.2 and 47.5 g/100g at the same time the spray-dried WEP was found to be 44.3 and 45.9 g/100g. Those however fell within the ranges of 41.76-48.75% reported by (Daramola, 2018; Koç *et al*., 2012; Ndife *et al*., 2010; Sujata, 2014) and (Asghar and Abbas, 2015).

As well, stastical significant diffrences ($P < 0.05$) were observed in beteween drying methods for both eag types. According to UNECE (2010) cited by (Kernels, 2013) concerning the marketing and commercial quality control of egg products stated that, the minimum protein content of dried WEP was 45.0 which relies on our study. Oven-dried, local and exotic breed WEP have revealed higher protein content than spray-dried WEP respectively, due to the influence of spray drier on protein structure. Also reported by Ayadi *et al*., (2008) , a slight decrease in the protein content of egg powder after spray-drying process was mentioned. This result could be explained by the heat denaturation of proteins present in the egg and chemical changes in amino acid residues induced by the spray-drying process (Anandharamakrishnan *et al*., 2007).

Table 8: Proximate composition of egg powder obtained from spray- and oven-drying of whole eggs from local (Ethiopian) and exotic (imported) chicken breeds

	Whole egg powder	
	Local	**Exotic**
Gross Energy (kcal/100g)		
Oven	572.8±0.9^{bA}	567.7±1.6^{aB}
Spray	579.3±1.9^{aA}	564.9±1.4^{aB}
Total Ash (g/100g)		
Oven	4.5±0.0^{aB}	4.7±0.0^{aA}
Spray	3.9±0.0^{bB}	4.1±0.0^{bA}
Crude Protein (g/100g)		
Oven	45.2±0.1^{aB}	47.5±0.4^{aA}
Spray	44.3±0.3^{bB}	45.9±0.2^{bA}
Crude Fat (g/100g)		
Oven	38.3±0.2^{bA}	37.4±0.3^{aB}
Spray	39.1±0.4^{aA}	36.3±0.3^{bB}
Crude Fiber (g/100g)		
Oven	0.12 ± 0.1^{aA}	0.18 ± 0.1^{aB}
Spray	0.09 ± 0.1^{bA}	0.08 ± 0.00^{bB}
Utilizable carbohydrate (g/100g)		
Oven	11.8±0.1^{bA}	10.2±0.7^{bB}
Spray	12.6±0.3^{aB}	13.6±0.2^{aA}

Values are expressed as mean ± SE (n=3). The different lowercase letters in the same column and different capital letters in the same row within the same parameter denote significant difference (P < 0.05) in mean comparisons using the student's independent t-test.

4.3.2. Crude Fat

The crude fat content was determined by the Soxhlet extraction method, and the results were discussed in (Table 8). In contrast, fat content was significantly higher in the egg powder from local egg tpyes. The fat content of WEP ranged between 36 g/100 g (exotic, spray-dried) to 39 g/100g (local, spray-dried). UNECE's (2010) report concerning the marketing and commercial quality control of egg products cited by (Kernels, 2013) stated that the minimum fat content of dried WE powder was 39 %. The slight difference from our study might be due to the solvent extraction system of the fat or type of feeding. Conferring to the result shown (Table 8), there was a significant difference between the fat content mean values of egg types statistically at $P < 0.05$.

Contrariwise, drying wise variation in this study for oven and spray drying were showed significant differences for their fat content at $P < 0.05$ statistically. The drying base variation of the fat content may be due to the egg powder processing conditions. Diets with high-fat content contribute significantly to the energy requirement for humans. WEP contributes more than 75% of fat requirements.

4.3.3. Total Ash

Ash content of WEP ranged from 3.9 (local-spray dried) to 4.7 g/100g (exotic-oven dried) (Table 8), showing a significant difference ($p < 0.05$). Exotic breed WEP have reflected higher ash content than the corresponding local breed WEP irrespective of the drying methods. As (Kudre *et al.*, 2018) in his study showed that quail egg powders had higher ash contents than resultant chicken egg powders ($P < 0.05$). Those findings advocated that eggs with a high amount of ash had a higher concentration of minerals compared to the low ash content eggs. Ash content of oven-dried local and exotic breed WE powder was (4.5, 4.7) g/100g at the same time to spray dried local and exotic breed WE powder was (3.9, 4.1) g/100g. The higher ash content of exotic breed WEP may arise from their feeding type, because the eggs were taken, from different types of sources.

Drying variation has also shown a significant difference in ash content mean value of local and exotic breed WEP at $P < 0.05$. Both for the local and exotic breed oven drying revealed higher ash content over spray drying, statistically. According to the results of (Jay *et al.*, 2000;Vaclavik *et al.*, 2008), described earlier the ash contents of WEP produced via spray drier was ranged from 2.4 to 2.81%. The drying variation was due to sieve size variation, spray-dried egg powders have fine products with small particle size.

4.3.4. Crude Fiber

The values of fiber content for each local and exotic breed WEP were given (Table 8) and the results ranged from 0.08 (exotic-spray dried) to 0.18 % (exotic-oven dried). This has been shown that, egg powder is among the food types containing the lowest (insignificant) level of fiber.The highest mean values of fiber content was found from exotic (0.18%) and local (0.12 %) oven-drieds WEP . The fiber content for egg-type variations were significantly different at $p < 0.05$. like wise in the egg type, drying variation has also been showed a significant difference in fiber content of local and exotic breed WEP. According to (Asghar and Abbas, 2015) the crude fiber content of spray-dried WEP varies from 0.94 to 1.1%. As stated by previous studies the fiber content of WEP ranged from 0.92 to 0.98 %, which close to the results of the current study but, slightly different, and this may be due to the milling method.

4.3.5. Carbohydrate

The utilizable carbohydrate of WEP was determined using a difference from the nutritional compositions of (moisture, ash, protein, and fat) out of a hundred. The utilizable carbohydrate was significantly higher in spray than in oven-dried powders ($P < 0.05$). The utilizable carbohydrate of oven-dried, local and exotic breed WEP was 11.8 and 10.2% while for the spray of WEP have 12.6 and 13.6 correspondingly. The carbohydrate content egg yolk powder in Leghorn egg was 4.58% and 7.02% in Turkey egg (Wei *et al*., 2019). As well, the drying wise study reflected (Table 8), that there was a significant difference between spray and oven drying for utilizable carbohydrate content at $p < 0.05$ statistically. Accordingly, local and exotic breed spray-dried WE powder reflected higher utilizable carbohydrate content (12.6, 13.6) % than oven-dried local and exotic breed WE powder with (11.8%, 10.2) % utilizable carbohydrate content respectively.

4.3.6. Gross Energy

The energy content of the egg powders obtained form 565 kcal (exotic-spray dried) to 579 kcal (local-spray dried). The energy content of the egg powder from the local breed was significantly higher than the exotic breed, irrespective of drying types $P < 0.05$ statistically. Drying only affected the energy content of the egg powder from the local breed. Significant variation was obtained in between drying types for the energy content at $P < 0.05$ over local breed WEP, but no significant difference on exotic breed WEP. The energy content produced by the oven and spray drying of local breed WEP was 572.8 and 579.3 kcal/100g mean while the exotic breed eggs produced by oven and spray drying is 567.7 and 564.9 kcal/100g, respectively.

4.4. Color

Color is one of the most important physical quality parameters that the consumer perceives and uses as a means to admit or castoff food (Goldberg *et al*., 2012).

The color examination can be conceded out by color measuring instrument or by human (visual) inspection. The decision of color in the human examination case is subjective and extremely variable from panelist to the panelist. To carry out a more objective color analysis, color standards (color spaces and numerical values) are often used as reference material that is used to create, represent and visualize colors in two and three-dimensional space (Crittenden *et al*., 2005; León Román, 2006). The RGB (red, green, and blue), the CMYK (cyan, magenta, yellow, black), and the L*a*b*color space are the three main color spaces that are used to define the color of foods. L* represents the lightness (L*=0 black and L*=100 white, b* represents the yellow-blue axis (-b*= blue and +b*= yellow) and a* represents redness (-a*=green and +a*=red).

Table 9: Color values of whole egg powder (L*a*b*) produced from Ethiopian local and exotic egg varieties using an oven and spray drying

	Whole egg powder	
	Local	Exotic
L-value		
Oven	74.04 ± 0.03^{bB}	81.31 ± 0.41^{bA}
Spray	78.03 ± 0.03^{aB}	82.93 ± 0.11^{aA}
a-value		
Oven	16.52 ± 0.12^{aA}	10.02 ± 0.17^{aB}
Spray	9.34 ± 0.02^{bA}	7.67 ± 0.02^{bB}
b-value		
Oven	65.47 ± 0.06^{aA}	22.95 ± 0.25^{bB}
Spray	42.00 ± 0.00^{bA}	24.27 ± 0.04^{aB}

Values are expressed as mean ± SE (n=3). The different lowercase letters in the same column and different capital letters in the same row within the same parameter denote significant difference (P < 0.05) in mean comparisons using the student's independent t-test.

Long time drying of food products at high temperatures can significantly decrease the quality of dried materials; color change (Koc *et al*., 2010). Similarly, during the spray drying of egg, the high-temperature application, might lead to Maillard reactions between glucose and amino acids present in the liquid egg. Also, the development of smaller particles after atomization can cause change in color of whole egg powder (Stadelman, 1995). With the understanding, the color values of WEP were evaluated as presented (Table 9). The results of whole egg powder color were ranged from L* (lightness) values 78.03 for local-spray dried to 82.93 for exotic spray-dried, while the color a*ranged from 7.67(exotic-spray dried) to 16.52 (local-oven dried) and color b* ranged from 22.95 (exotic-oven dried) to 65.47 (local-oven dried) whole egg

According to the result shown (Table 9), there was a significant difference between the color values of L*, a*, and b* mean value of egg types statistically at $p < 0.05$. Exotic breed WE powder have shown higher L* (lightness) value than local breed WE powder irrespective of the drying method. This might be due to genetics, feed type and presence of the deep yellow egg yolk index . On the other hand, a* (redness) and b* (yellowness) values of the local egg WEP was significantly higher than in the exotic breed WEP irrespective of the drying methods.

There was a significant difference ($P<0.05$) in L*, a* and b* values in the WEP up on the drying methods. Spray dried WEP had higher L* lightness values than the oven dried one both for local and exotic breed eggs. In contrast, a* redness value was higher in the oven dried WEP than the spray dried one. Similarly, the b* yellowness value of the oven dried local WEP was higher than the value in the spray dried powder. However, the rever trend was observed for the exotic egg breed, in which spray dried WEP had higher b* yellowness value (Table 9). In all cases, the spray-dried egg powders had more lightness (*L**) than the oven-dried, and this corroborated more intens color on the spray dried WEP. Egg color correlates mainly with the content of oxycarotenoids; their concentrations are linked to intensity of color, hence their quantities are higher in spray-dried egg powders.

4.5. Functional property of whole egg powder

Functional properties are the intrinsic physicochemical properties that reflect the complex interaction between the composition, structure, and confirmation, of protein and other food components, and the nature of the environment associated and measured (Kinsella and Melachouris, 1976). It affects the behavior of food systems during processing and storage. Egg powders can be added to the various food products to fortify them for enhancing nutritional content and provide functionality (Stadelman, 1995). Passable knowledge of these properties indicates the usefulness and acceptability of a product.

Drying conditions have shown an effect on the functional, physical, and chemical properties of the EP during the transformation of a pasteurized liquid WE into WEP (Koc *et al.*, 2010). Foaming capacity, Emulsification capacity, Water absorption capacity, Oil absorption capacity, the soluble protein content of the WEP were analyzed to understand their role in the product qualities.

4.5.1. Soluble protein content

Protein solubility is considered as a criterion for the major functional properties including gelation, emulsification, and foam formation (Talansier *et al*., 2009). Additionally, protein solubility of all egg powders may serve as a useful indicator for the performance of egg proteins in the food formulation. In this study, the soluble protein content ranged between 47.4% (spray-dried exotic) and 51.7% (oven-dried exotic). A significant difference in soluble protein between egg types was only observed for oven dried powder ($P < 0.05$). The SPC of oven-dried local and exotic breed WE powder was 49.6 and 51.7%, respectively. Meanwhile, the SPC value in spray dried local and exotic breed WE powder was 48.3 and 47.4%, respectively. (Kudre *et al*., 2018) stated that, the higher solubility of dried egg powders might be due to differences in protein types, amino acid compositions, and degrees of association or dissociation of protein molecules. The protein solubility profile studied in this study resembles those already reported for egg albumin and yolk protein by Machado *et al*., (2007).There was a significant difference in SPC values up on the two drying methods ($P<0.05$).

4.5.2. Foaming capacity

The foaming ability of dried egg is an important functional property, which finds application in confectionery and aerated foods (Ayadi *et al*., 2008). The foaming property of WEP played a vital role in the stability of ice cream and cream products (Albert, 1997; Wilcox, 2006). There was no significant difference in foaming capacity in between drying methods and egg types ($P < 0.05$). The foaming capacity of oven-dried, local and exotic breed WEP was (31.2, 33.9) % as compared to the spray-dried, local and exotic breed WEP which is (29.5, 30.5) %. Surface-active film foaming compounds, such as proteins, serves foaming capacity and stability of dried egg powder (Kinsella and Morr, 1984). Though WEP has no significant difference in their foaming capacity, high protein solubility correlates with the foaming ability of WEP.

The high foaming capacity also suggests that the drying process did not induce significant denaturation of proteins (Oboroceanu *et al*., 2014; Xiong, 1997). (Asghar and Abbas, 2015) reported that the foaming capacity of WEP was in the range of (31-36) % and this is in agreement with the present finding. Following (Yang *et al*., 2010) also found that spray-dried WEP has shown a foaming capacity of 40 % and (36-40) % (Ndife *et al*., 2010). While the foaming capacity of foam-mat dried local and poultry WEP was ranged from (17-18.2) % (Orishagbemi *et al*., 2017), which is lower than the current findings.

Table 10: Functional properties of whole egg powder produced from Ethiopian local and exotic egg varieties using oven and spray drying

	Whole egg powder	
	Local	**Exotic**
Foaming capacity (%)		
Oven	31.2 ± 0.9^{aA}	33.9 ± 0.9^{aA}
Spray	29.5 ± 0.9^{aA}	30.5 ± 0.9^{aA}
Emulsion capacity (%)		
Oven	55.1 ± 1.2^{aB}	56.8 ± 2.4^{aA}
Spray	54.5 ± 1.2^{aA}	55.0 ± 1.0^{bA}
Water absorption capacity (ml/g)		
Oven	1.5 ± 0.1^{aB}	1.6 ± 0.1^{bA}
Spray	1.1 ± 0.1^{bB}	2.2 ± 0.3^{aA}
Oil absorption capacity (ml/g)		
Oven	0.9 ± 0.0^{bB}	1.2 ± 0.1^{aA}
Spray	1.1 ± 0.0^{aA}	1.2 ± 0.1^{aA}
Soluble protein content (%)		
Oven	49.6 ± 0.2^{aB}	51.7 ± 0.1^{aA}
Spray	48.3 ± 0.1^{bA}	47.4 ± 1.9^{bA}

Values are expressed as mean ± SE (n=3). The different lowercase letters in the same column and different capital letters in the same row within the same parameter denote significant difference (P < 0.05) in mean comparisons using the student's independent t-test.

4.5.3. Emulsification capacity

A whole egg is used as an emulsifier for many food formulation and preparation. The average emulsion capacity was 55 ml/g with a slight, but significant difference was showing between local and exotic oven drying WEP. The emulsification capacity of oven-dried local and exotic breed WEP was 55.1 and 56.8) % where the spray-dried local and exotic breed is 54.5 and 55.0) %. As (Ndife *et al*., 2010) report the emulsification capacity of oven-dried WEP was 55% which is in agreement with the existing findings in this study. Alternatively, spray-dried WEP obtained by (Ndife *et al*., 2010) has reflected a lower value as compared to this finding.

Drying type variations for the emulsification capacity of WEP produced by oven and spray dryings were also presented (Table 10). Accordingly, local and exotic breed of WEP by spray drying have revealed a significant difference in their emulsification capacity mean value statistically at $P < 0.05$. (Orishagbemi *et al*., 2017) reported that the emulsion capacity of foam-mat drying local and poultry WEP were 44.8% and 32.00%. It was also reported that the spray drying process, itself, could even improve the emulsion stability of egg powder (Koç *et al*., 2011).

4.5.4. Water absorption capacity

Water Absorption Capacity is desirable in food systems to improve yield and consistency and provide physique to the food (Osundahunsi *et al*., 2003). Variation in WAC of WEP may be due to differences in concentration of protein, their degree of interaction with water, and possibly their conformational characteristics. The result obtained for WAC for this study was ranged between 1.1 to 2.2 ml/g. the WAC of oven-dried, local and exotic WEP (1.5, 1.6 ml/g) has a higher mean value as compared to spray-dried, local and exotic WEP (1.1, 2.2) ml/g . According to statistical statistical independent t-test comparison at $P < 0.05$, there was a significant difference between the WAC of drying and egg types. This is in line with the findings for the oven-drying WEP reported by (Ndife *et al*., 2010), the average WAC recorded was 1.6 ml/g. The results in this study also reflected similar WAC ranges of 1.90 to 2.25 ml/g as described in the study of (Valerie-Lechevalier *et al*., 2007).

4.5.5. Oil absorption capacity

The hydrophobic property of fats reduces the ability of the dried egg powder to absorb water. Absorption of oil by food products improves mouthfeel and flavor retention. The higher OAC suggests the lipophilic nature of flour constituents (Ubbor and Akobundu, 2009). On the other hand, 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. OAC data can be used to predict the palatability of a WEP-based product since oil increases mouthfeel and retains flavor (Aremo and Olaofe, 2007; Aremu *et al*., 2007; Kumaravel *et al*., 2011).

The OAC presented (Table 10), was ranged between 0.9 (oven-dried local) to 1.2 (oven/spray-dried exotic), but the results reflected a very narrow range in OAC variability in egg-types. There was no significant difference between the OAC mean of spray-dried egg-types, whereas oven-dried egg-types have reflected a significant difference statistically at $P < 0.05$. The oil absorbtion capacity was significantly higher in exotic breed WEP at $P < 0.05$, irrespective of the drying methods. (Ndife *et al*., 2010) in his study showed that the OAC of oven-dried WEP was 2.6 g/g.

4.6. Macro-mineral composition of whole egg powder

The macro-mineral composition of the WEP such as calcium, magnesium, potassium, sodium, and Phosphorus was analyzed and results were given (Table 11).

Table 11: Macro-mineral composition (mg/100g) of whole egg powder produced from Ethiopian local and exotic egg varieties using oven and spray drying

Whole egg powder		
	Local	**Exotic**
Calcium		
Oven	197.0 ± 0.2^{bA}	120.0 ± 0.1^{bB}
Spray	326.0 ± 0.5^{aA}	341.0 ± 0.4^{aA}
Potassium		
Oven	920.0 ± 0.3^{aA}	912.0 ± 0.1^{aA}
Spray	834.0 ± 0.0^{bA}	818.0 ± 0.1^{bA}
Magnesium		
Oven	121.0 ± 0.2^{aA}	95.0 ± 0.0^{aA}
Spray	92.0 ± 0.1^{aA}	82.0 ± 0.0^{bA}
Phosphors		
Oven	184.0 ± 0.1^{aA}	176.0 ± 0.1^{aA}
Spray	143.0 ± 0.1^{bB}	181.0 ± 0.1^{aA}
Sodium		
Oven	521.0 ± 0.4^{aA}	494.0 ± 0.0^{bA}
Spray	457.0 ± 0.0^{bB}	488.0 ± 0.5^{bB}

Values are given as mean ± SE (n=3). The different lowercase letters in the same column and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test.

Some of the minerals are not disaggregated by drying type as this does not affect mineral content. No significant differences between egg powders for spray-dried, local and exotic breeds were observed for calcium, magnesium, potassium, and sodium. Phosphorus was however significantly higher in the egg powder from the exotic than the local breed ($P < 0.05$). While for the oven-dried only calcium was significantly higher in the egg powder for local than exotic breed at $P < 0.05$.

The significant difference in mineral content of local and exotic breed eggs might be due to the difference in the rearing system of hens, and feed types. Our assumption was in agreement with arguments by Küçükyılmaz *et al*., (2012); Matt *et al*., (2009) egg mineral contents showed variable responses to the hen rearing systems. Several investigations have shown that, macroelements (including Ca, P and Mg) are provided by both feed ingredients and supplemental mineral rocks, such as limestone and dicalcium phosphate Küçükyılmaz *et al*., (2012).

4.7. Trace-mineral composition of whole egg powder

The trace-mineral composition of the WEP such as Iron, Zinc, Manganese and copper was analyzed and results were presented (Table 12).

Table 12: Trace-mineral composition (mg/100g) of whole egg powder produced from Ethiopian local and exotic egg varieties using the oven and spray drying

Whole egg powder		
	Local	**Exotic**
Iron		
Oven	17.0 ± 0.0^{aA}	11.0 ± 0.0^{bB}
Spray	11.0 ± 0.0^{bB}	14.0 ± 0.0^{bB}
Zinc		
Oven	1.36 ± 0.2^{aA}	1.09 ± 1.7^{aB}
Spray	1.18 ± 2.5^{aA}	1.19 ± 1.5^{aA}
Manganese		
Oven	0.25 ± 0.3^{aA}	0.19 ± 0.2^{aB}
Spray	0.12 ± 0.1^{bB}	0.16 ± 0.1^{aA}
Copper		
Oven	0.31 ± 0.1^{aB}	0.39 ± 0.0^{aA}
Spray	0.27 ± 0.2^{aA}	0.26 ± 0.3^{bA}

Values are given as mean ± SE (n=3). The different lowercase letters in the same column and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the independent t-test.

No significant differences between egg powders fo spray-dried, local and exotic breeds were observed for iron, zinc, and copper. Manganese was however significantly higher in the egg powder from the exotic than the local breed ($P < 0.05$). While, for the oven-dried iron, zinc, and manganese was significantly higher in the egg powder from the local than exotic breed egg-types, whereas copper was significantly higher in exotic egg-types statistically at $P < 0.05$. From the presnte study, we aimed to provide a baseline of the composition of chicken eggs in micro minerals. To the extent that consumption of eggs by humans is concerned, chicken eggs are recognized increasingly as an important source of nutrients, including micro minerals (Surai and Sparks, 2001). Currently, there is considerable interest in the trace mineral composition of eggs from the perspectives of human health (Kilic et al., 2002).

4.8. Rating acceptance sensory evaluation of whole egg powder

The mean scores of the sensory attributes of the WEP is presented (Table 13). The result on each attribute is described and discussed as below. The oven dried WEP from both egg types had higher appearance score than the spray dried product ($p<0.05$). The local and exotic oven-dried WEP had the highest appearance rating of 6.0 and 5.7, respectively. Meanwhile, the local spray-dried WEP was the least appreciated (Table 13). There was no significant difference in appearance score of WEP based on egg types with both drying methods ($p>0.05$).

For the taste attribute evaluation, WEP was added into legume based Ethiopian stew (Shiro) with the preparation method described in materials and methods section. Accordingly, the taste of the oven and spray dried WEP from both egg types were the most (6.1) and least (5.3), preferred products respectively. Regardless of the egg type, the oven dried WEP had higher taste score than the spray dried product ($p<0.05$). In contrast, no significant difference in taste score based on the type of eggs with both drying methods ($p>0.05$). In Europe, many consumers believe that, eggs originating from free-range farms taste better, over conventional eggs (Rodić *et al*., 2006).

Color is an important sensory attribute that generally enhances the acceptability of a product. For the local egg based WEP, oven drying had a higher color score than spray drying ($p<0.05$). No significant difference was observed for the exotic egg type based WEP ($p>0.05$). The panelists preferred the color of the local egg based powder regardless of the type of drying. Accordingly, oven- and spray-dried local WEP had a sensory color score of 6.3 and 5.5, respectively. The panelists preferred the odor of the local egg based spray dried WEP to the oven dried product.

However, this trend was not observed for the exotic egg based powder, in which there was no significant difference $P \geq 0.05$ between the two drying methods. For the oven dried powder, the exotic egg based powder had a higher odor score than the local ($p<0.05$), $P \geq 0.05$ No significance difference was observed for the spray died powder based on egg types..

Table 13: Rating acceptance sensory evaluation of whole egg powder produced from Ethiopian local and exotic egg varieties using the oven and spray drying

Whole egg powder		
	Local	Exotic
Appearance		
Oven	6.0 ± 0.9^{aA}	5.7 ± 1.1^{aA}
Spray	5.2 ± 1.0^{bA}	4.9 ± 1.0^{bA}
Color		
Oven	6.3 ± 0.9^{aA}	5.3 ± 1.1^{aB}
Spray	5.5 ± 1.1^{bA}	4.8 ± 1.1^{aB}
Odor		
Oven	5.0 ± 1.1^{bB}	5.3 ± 1.1^{aA}
Spray	5.7 ± 1.0^{aA}	5.4 ± 0.9^{aA}
Texture		
Oven	5.7 ± 0.7^{aA}	5.9 ± 0.9^{aA}
Spray	5.9 ± 0.9^{aA}	5.3 ± 0.9^{bB}
Overall acceptability		
Oven	5.8 ± 0.9^{aA}	5.5 ± 0.8^{aA}
Spray	5.6 ± 1.0^{aA}	5.1 ± 0.9^{bB}

Sensory scores are given as mean ± SD (n =16 semi-trained panelists) using 7 points hedonic scale, where 7-Extremely Like; 1-Extremely Dislike. The different lowercase letters in the same column, different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using student's independent t-test.

The texture attribute of whole egg powder irrespective of the drying methods ranged from 5.3 to 5.9. The exotic oven dried WEP had higher texture score than the spray dried product ($p<0.05$) Spray drying process and conditions have influence on the texture of whole egg powder, which is strongly depends on protein denaturation (Franke and Kießling 2002; Campbell et al. 2003). But there was no significance difference in texture scores in the local egg type powders ($p>0.05$). The exotic and local egg-types of oven/spray-dried whole egg powders have shown an acceptable assortment. There was no significance difference in the overall acceptability score between oven and spray dried local WEP ($p>0.05$). The reverse was true for the exotic WEP. There was no significant difference in the overall acceptability of the oven dried WEP among the egg types ($p>0.05$). But the local spray dried WEP had higher overall acceptability than the exotic based powder.

4.9. Contribution to nutrient intake

The nutritional contribution of WEP (1 egg equivalent) relative to the proposed nutrient composition in complementary foods is reported (Table 14). Among the studied nutrients, except for manganese and zinc, egg powders equivalent to one egg contributed to > 50% of the proposed daily requirement from complementary foods. The protein contribution was close to 200%, suggesting that even 6 g of dried product (half an egg) can allow children to meet their protein requirements. The contribution of 12.5 g of WEP was more than 75% and 30% of the fat and energy requirements, respectively.

Table 14: Contribution of whole egg powder to selected nutrients requirements from complementary foods and ready-to-use therapeutic food

	Contribution to Requirements (%)		
	Requirements§	**local**	**exotic**
		1 egg equivalent ~12.5 g	
Energy (kcal)	220	34	33
Protein, g	3-5.5	190	196
Fat, g	6.3	80	74
Calcium, mg	100-200	42	44
Copper, µg	200-400	26	17
Iron, mg	7.0-11.0	20	26
Manganese, mg	0.6	5	3
Phosphorus, mg	75-100	24	31
Zinc, mg	4.0-5.0	4	4

CF, complementary foods; § requirements are based on the proposed composition of complementary foods described in (Lutter & Dewey, 2003)

The findings from the proximate and mineral composition illustrated the potential of egg powders to contribute to meeting the high nutritional requirements of children. A key constraint in the formulation of nutrient-dense complementary foods is related to the very low gastric capacity of children (Baye, Tariku, & 2018). This requires packing as many nutrients as possible in a small quantity/volume. An equivalent of one egg, in the form of egg powder (~12.5 g) can fulfill > 75% of fat, > 30% of energy, and close to half of the calcium requirements. With just 6 g of whole egg powder, the protein requirements can be fulfilled, and with only ~4 g (about 1/3 of an egg= 49 mg choline), 100% of choline requirements (45.9 mg) can be fulfilled.

4.10. Shelf stability of whole egg powder

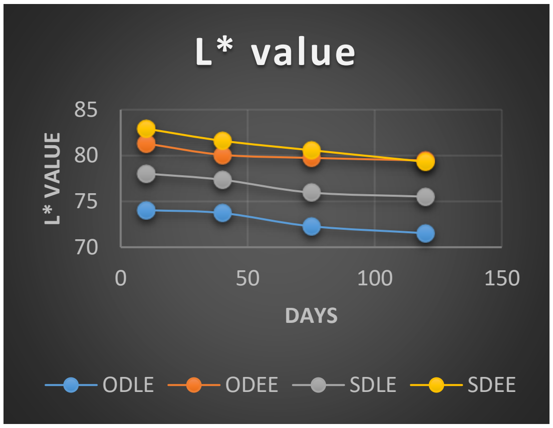
The shelf stability of the presnt study was includes; moisture content, water activity, pH, peroxide value,TAMB, total coliforms, and salmonella. Although some differences were observed by drying method and egg type, the low moisture and water activity of the WEP confirm the anticipated advantage of extending the shelf-life. With such low moisture content and water activity, the powders are less susceptible to microbial growth (Labuza and Rahman, 2007). The shelf-life of egg powder can be prolonged from two weeks (unprocessed eggs) to 6-12 months at ambient temperature (Sharif *et al*., 2018).

In the present study, the shelf stability of the WEP was evaluated at two storage temperatures (temperate (23^{o}C) and tropical (38^{o}C) and with two packaging materials (plastic cup and aluminum foil). The powder samples were taken on monthly basis to evaluate the shelf stability for a total of 4 months period of time. Results are presented in (Tables 15 - 19) and (Figures 6 and 7).

4.10.1. The color change of whole egg powder during storage

The color was measured by an absolute measuring mode following the manufacturer's instruction and calculated automatically using the CIE 1976 L⁄a⁄b⁄ color space system (Jackson *et al.*, 2018). The color values (L*, a*, and b*) of powdered egg were evaluated at a temperate temperature stored for 1, 2, and 4 months and the control (the sample just oven/spray-dried) as shown in (Figures 6 and 7). In samples stored at room temperature, L* value decreased markedly, from its initial value to 4-month storage from 78.03 to 71.53 for oven/spray-dried local egg whereas oven/spray-dried exotic egg L* value was decreased from 82.93 to 79.32. However, a proportional increase of a* and b* values in samples stored at the same temperature was not shown a linear consistency.

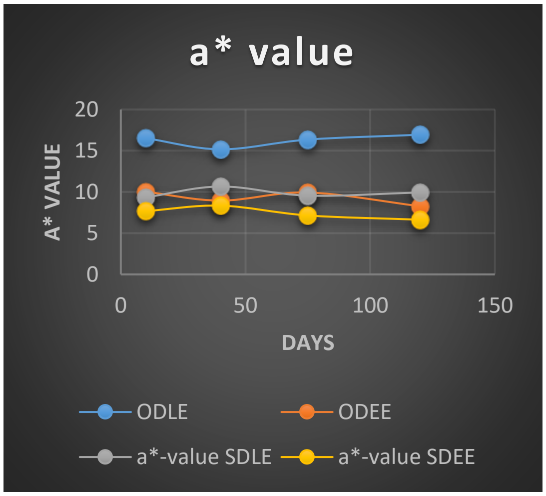
The lightness (L* value) of dried egg powder was decreased during the storage period. The results of this study showed that there was a significant difference ($p < 0.05$) in the lightness (L* value) of WEP samples with different egg-types and drying methods. As shown (Figure 9), the lightness of WEP samples was ranging from 82.93 - 71.53. The exotic breed WEP were reflecting a higher



L* value as compared to the local breed egg powders. The lightness difference between the egg-types might be due to various factors like hen breed, and feed type (more leafy vegetables of higher chlorophyll leads to a concentrated yellow yolk index), as a result L* value of the egg decreases. On the other hand, the drying effect has also shown a significant difference in the L* value of WEP significantly at $P < 0.05$.

Figure 6: Change of (L* value) as a function of time of dried whole egg powder during storage at room temperature; *ODLE- oven-dried local egg, ODEE- oven-dried exotic egg, SDLE- spray-dried local egg, SDEEspray-dried exotic egg*

The L* value of WEP was decreased starting from the beginning to the fourth month storage period. One of the reasons which cause a color change in dry systems was the non-enzymatic browning by the presence of amines and reduced sugars (Rao and Labuza, 2012). Besides this, the L* value of WEP was decreased significantly as the water activity of the stored sample increases compared to those at lower water activity. This pattern as a function of water activity has in an agreement with previous studies by Rao *et al*., (2012).



Accordingly, Guo, (2016) has reported that the color change (a decrease of L* value) was mostly due to the Maillard reaction and lipid oxidation, as the products stored at a set of temperature and water activity using multiple techniques, and their quantities increased with increasing storage time. Bell, (2020) also stated that L* value decreased with increment in the moisture content of the dried egg, which is with greater moisture adsorption, more reactants dissolved and their mobility further increased, resulting in faster reaction rates.

The a*(red/magenta-green) value of the whole egg powder was reflecting a higher value for oven-dried local egg types as compared to the other dried whole eggs. As shown (Figure 7), a* value of whole egg powder was in the range of (6.63 to 16.94). During the storage period, a* value of whole egg powder was showing a significant difference at $P < 0.05$ statistically. Even if a* value was slightly decreased after one month for those oven-dried egg powders, whereas spray-dried WE powders were slightly increased. The b* value of whole egg powder during the storage period was ranged from (21.76 – 65.47) as shown (Figure 7), below. Local breed egg-type was reflecting a higher b*value as compared to exotic breed egg-type irrespective of the drying methods. For the drying methods, oven drying has reflected a higher b*value in comparison with the spray drying both for the local and exotic egg types at $P < 0.05$ statistically.

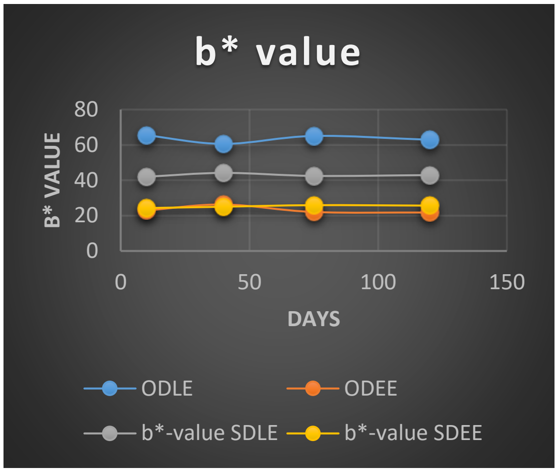


Figure 7: Change of (a* and b*values) as a function of time of dried whole egg powder during storage at room temperature; *ODLE- oven-dried local egg, ODEE- oven-dried exotic egg, SDLE- spray-dried local egg, SDEEspray-dried exotic egg*

period. The b* of WEP illustrated the deep yellowness of the egg yolk index, and this emphasizes a decrease in the L* of the egg powder which might lead to lipid oxidation. In contrast to the other main reasons, the color change of whole egg powder was also due to the possible oxidation of yellow pigments of carotenoids (Guo, 2016). (Guardiola *et al*., 1997) also explained that this phenomenon, based on storage experiments of egg powder, was by the reason of loss of β-carotene during prolonged storage. However, the presence of xanthophyll's in egg has an antagonistic effect on the color change, since is capable of reducing rate of increase of peroxide value (lipid oxidation) by carotenoids due to their antioxidant activity (Laguerre *et al*., 2007).

4.10.2. Moisture content of whole egg powder during storage

Resultes presented in (Table 15) shows that, the effect of storage period on the moisture content of whole egg powders. The moisture content of WEP was in the range of 2.0-7.5 g/100g. There were significant differences ($P<0.05$) in moisture content of the WEP based on egg type, drying methodsand storage materials. Along the storage period egg-types and drying methods have shown a significant difference on the mean value of moisture content of WE powder. The moisture content of local and exotic WEP stored at room temperature using a plastic cup from the first month and fourth month was significantly highest.

The highest value for moisture content of egg powders was recorded in month one, while the lowest values were recorded in month three irrespective of the drying methods stored at temperate temperature using a plastic cup storage material. The moisture content of whole egg powder has been shown a significant difference for the oven/ spray-dried local and exotic whole egg powders stored at different storage conditions of temperate and tropical temperatures using a plastic cup and aluminum foils.

Whole egg powders stored at a tropical temperature (38^{o}C) month one powder significantly ($P<0.05$) had the highest value for moisture content while the lowest value were recorded in month three and two respectively. The whole egg powder stored at room temperature using aluminum foil had the highest moisture content as compared to the other storage conditions. In this storage condition the highest moisture content were recorded in month four whereas the lowest moisture content were recorded in month two. The moisture content of whole egg powder stored at (38^{o}C) was lowest compared with the value in room temperature stored powder with the same packaging material. Apparently this might be due to high temperature and low humid air during the storage period. Overall month four powder had significantly ($P<0.05$) the highest moisture content.

Moisture is an important parameter in baked foods that significantly affects shelf life and growth of microbial contaminants (Teshome *et al*., 2017). Low moisture contents of egg powder samples (4.8 - 5.1) % indicates low water activity which would ensure good keeping quality when packed in moisture and gas-proof package with hermetic sealing (Orishagbemi *et al*., 2017; Vega-Mercado *et al*., 2001).

4.10.3. The water activity of whole egg powder during storage

Water activity is more related to shelf stability of food products than moisture content. The microbial, chemical and physical properties of food products are more closely related to the water activity of the product (Sablani *et al*., 2007). The water activity of whole egg powder was in the range of (0.44 – 0.66) during the storage stability study as shown (Table 16) below. The water activity of dried egg powders along the storage period had increased from its initial production to four month of storage period. However, some inconsistency was observed especialy on the tropical temperature, and this might be due to relative humidity variation on the external environment.

Whole egg powders stored in tropical temperatures(~38^{o}C) using aluminum foil packaging material were reflecting higher water activity in comparison to the other storage conditions. The dried egg powders stored at room temperature using aluminum foil packaging material had reflecting higher water activity than plastic cup stored product. Meanwhile, egg powders stored at a tropical temperature using plastic cup had higher water activity value in contrast to egg powders stored using aluminum foil storage material. According to (Labuza, 1980) water activity has a vital role and played a greater impact on microbial growth, chemical reaction rate, and physical changes.

Both at temperate and tropical storage conditions the water activity of dried egg powders was showing a significant difference at $P< 0.05$ even if it is on a closed range between egg-types and drying methods. The water activity of the whole egg powder was preferably susceptible for lipid oxidation rather than the microbial load growth., In general, spray dried whole egg powders had lower water activity than oven dried once along the storage period at room and tropical temperature using plastic cup and aluminum foil packaging materials.

4.10.4. pH value of whole egg powder during storage

The pH value of local and exotic whole egg powder was (6.64 - 7.76) and (6.84 – 8.62) respectively. Typically, the pH value of dried whole egg was showing a significant difference between the drying methods and egg types ($P < 0.05$). Oven/spray-dried exotic breed whole egg powders were reflecting higher pH value as compared to the local breed whole egg powders, irrespective of their drying methods and storage conditions. Kind of powder, time, and way of storage conditions had a significant impact on the changes of pH (Chudy et al., 2015).

The dried whole egg powders stored at temperate and tropical storage temperatures have also shown significantly different for pH value in both local and exotic breed whole egg powders. On behalf of this, egg powders stored at room temperature reflected higher pH than those stored at temperate temperatures. This might be due to the moisture content variation among the egg powders, in which electrolytes were freely mobile at higher water content relative to the lower moisture content along the storage period. Exotic breed whole egg powders exhibited higher pH value over the local breed whole egg powders irrespective of their drying types and storage conditions. The higher pH value of this finding becomes due to the change in the moisture content of the whole egg powders or due to their feeding types (Sharif *et al*., 2018).

Table 15: Moisture content (g/100g) of whole egg powder during storage

		Moisture content (g/100g)							
Storage time	Drying method	Egg-type							
		Local				Exotic			
Time-0	Oven	3.63 ± 0.02^{bA}				4.25 ± 0.05^{bB}			
	Spray	2.56 ± 0.09^{aA}				3.39 ± 0.03^{aB}			
		P25		P38		A25		A38	
		Local	Exotic	Local	Exotic	Local	Exotic	Local	Exotic
First month	Oven	4.21 ± 0.13^{bA}	5.65 ± 0.05^{bB}	4.55 ± 0.58^{bA}	5.29 ± 0.05^{bB}	5.19 ± 0.05^{aA}	6.63 ± 0.06^{bB}	3.17 ± 0.03^{bA}	3.83 ± 0.03^{bB}
	Spray	3.38 ± 0.03^{aB}	3.14 ± 0.02^{aA}	3.36 ± 0.04^{aB}	3.21 ± 0.05^{aA}	5.46 ± 0.00^{bB}	5.44 ± 0.03^{aB}	3.09 ± 0.01^{aA}	3.08 ± 0.02^{aA}
Second month	Oven	3.23 ± 0.01^{bA}	5.12 ± 0.03^{bB}	3.19 ± 0.01^{bA}	4.38 ± 0.01^{bB}	5.41 ± 0.00^{bA}	5.94 ± 0.00^{bB}	2.54 ± 0.00^{aA}	3.30 ± 0.01^{bB}
	Spray	3.00 ± 0.01^{aA}	3.18 ± 0.01^{aB}	2.79 ± 0.00^{aB}	2.65 ± 0.01^{aA}	5.06 ± 0.00^{aA}	5.77 ± 0.02^{aB}	2.59 ± 0.00^{bA}	3.14 ± 0.01^{aB}
Third month	Oven	2.72 ± 0.00^{aA}	4.08 ± 0.00^{bB}	2.55 ± 0.00^{bA}	3.44 ± 0.00^{bB}	6.83 ± 0.00^{bA}	7.25 ± 0.00^{bB}	3.13 ± 0.00^{bA}	3.51 ± 0.00^{bB}
	Spray	2.75 ± 0.00^{bB}	2.12 ± 0.00^{aA}	1.69 ± 0.00^{aB}	1.66 ± 0.00^{aA}	5.98 ± 0.00^{aA}	6.55 ± 0.00^{aB}	2.97 ± 0.00^{aA}	3.27 ± 0.00^{aB}
Fourth month	Oven	3.38 ± 0.01^{aA}	5.42 ± 0.04^{bB}	3.74 ± 0.25^{bA}	5.09 ± 0.54^{bB}	6.67 ± 0.59^{bA}	7.48 ± 0.40^{bB}	3.94 ± 0.18^{bA}	4.35 ± 0.13^{bA}
	Spray	5.48 ± 0.16^{bB}	3.03 ± 0.18^{aA}	2.69 ± 0.52^{aA}	3.58 ± 0.55^{aB}	6.37 ± 0.45^{bB}	$7.04 \pm 0.5b^{bB}$	3.84 ± 0.02^{bA}	4.71 ± 0.07^{aB}

Values are given as mean $\pm$ SD (n=3). The different lowercase letters in the same column and different capital letters in the same row within the same storage temperature and packaging material denote a significant difference ($P < 0.05$) using the student's independent t-test.

A: aluminum foil packaging material; P: plastic cup packaging material; 25: storage room temperature; 38: tropical storage temperature

Table 16: The water activity of whole egg powder during storage

		Water activity							
Storage time	Drying method	Egg-type							
		Local				Exotic			
Time-0	Oven	0.47 ± 0.00^{bA}				0.48 ± 0.02^{bB}			
	Spray	0.44 ± 0.01^{aA}				0.46 ± 0.00^{aB}			
		P25		P38		A25		A38	
		Local	Exotic	Local	Exotic	Local	Exotic	Local	Exotic
First month	Oven	0.50 ± 0.00^{aA}	0.57 ± 0.00^{bB}	0.52 ± 0.01^{bA}	0.57 ± 0.01^{bB}	0.54 ± 0.01^{bA}	0.58 ± 0.01^{bB}	0.53 ± 0.01^{bB}	0.51 ± 0.01^{bA}
	Spray	0.50 ± 0.00^{aB}	0.49 ± 0.01^{aB}	0.49 ± 0.01^{aA}	0.52 ± 0.01^{aB}	0.57 ± 0.02^{bB}	0.54 ± 0.01^{aA}	0.49 ± 0.01^{aA}	0.51 ± 0.00^{bB}
Second month	Oven	0.50 ± 0.00^{aA}	0.56 ± 0.01^{bB}	0.53 ± 0.01^{bA}	0.54 ± 0.01^{bB}	0.59 ± 0.02^{bA}	0.63 ± 0.01^{bB}	0.51 ± 0.01^{bB}	0.49 ± 0.01^{aA}
	Spray	0.53 ± 0.01^{bB}	0.48 ± 0.02^{aA}	0.51 ± 0.01^{aA}	0.51 ± 0.01^{aA}	0.60 ± 0.01^{bB}	0.60 ± 0.02^{bB}	0.49 ± 0.01^{aA}	0.50 ± 0.00^{bA}
Third month	Oven	0.52 ± 0.01^{aA}	0.56 ± 0.02^{bB}	0.54 ± 0.01^{bB}	0.53 ± 0.01^{bA}	0.66 ± 0.01^{bB}	0.65 ± 0.01^{bB}	0.49 ± 0.01^{aB}	0.48 ± 0.01^{aA}
	Spray	0.56 ± 0.00^{bB}	0.47 ± 0.03^{aA}	0.50 ± 0.01^{aA}	0.52 ± 0.01^{bB}	0.64 ± 0.01^{aA}	0.63 ± 0.01^{bB}	0.47 ± 0.02^{aA}	0.49 ± 0.02^{aB}
Fourth month	Oven	0.47 ± 0.02^{aA}	0.55 ± 0.03^{bB}	0.47 ± 0.01^{aA}	0.56 ± 0.01^{bB}	0.61 ± 0.01^{bA}	0.64 ± 0.01^{bB}	0.4 6± 0.01^{aA}	0.49 ± 0.01^{aB}
	Spray	0.57 ± 0.01^{bB}	0.46 ± 0.01^{aA}	0.46 ± 0.01^{aA}	0.50 ± 0.01^{aB}	0.62 ± 0.01^{bB}	0.63 ± 0.01^{bB}	0.48 ± 0.01^{aB}	0.45 ± 0.02^{aA}

Values are given as mean ± SD (n=3). The different lowercase letters in the same column and different capital letters in the same row within the same storage temperature and packaging material denote a significant difference (P < 0.05) using the student's independent t-test

A: aluminum foil packaging material; P: plastic cup packaging material; 25: storage room temperature; 38: tropical storage temperature

Table 17: pH of whole egg powder during storage

		pH							
Storage time	Drying method	Egg-type							
		Local				Exotic			
Time-0	Oven	7.46 ± 0.03^{aB}				8.62 ± 0.01^{aA}			
	Spray	7.76 ± 0.01^{aB}				8.53 ± 0.00^{aA}			
		P25		P38		A25		A38	
		Local	Exotic	Local	Exotic	Local	Exotic	Local	Exotic
First month	Oven	7.15 ± 0.03^{bB}	8.17 ± 0.01^{aA}	7.07 ± 0.01^{bB}	7.36 ± 0.01^{bA}	7.19 ± 0.02^{bB}	8.33 ± 0.01^{aA}	6.87 ± 0.02^{bB}	7.68 ± 0.01^{aA}
	Spray	7.60 ± 0.01^{aA}	8.11 ± 0.01^{bA}	7.13 ± 0.00^{aB}	7.54 ± 0.01^{aA}	7.22 ± 0.00^{aB}	8.24 ± 0.02^{bB}	7.07 ± 0.02^{aB}	7.51 ± 0.01^{bA}
Second month	Oven	7.17 ± 0.00^{bB}	8.18 ± 0.01^{aA}	6.71 ± 0.01^{bB}	7.05 ± 0.02^{bA}	7.29 ± 0.01^{aB}	8.17 ± 0.06^{aA}	6.72 ± 0.02^{bB}	7.24 ± 0.02^{aA}
	Spray	7.58 ± 0.02^{aB}	8.09 ± 0.00^{bA}	6.86 ± 0.01^{aB}	7.09 ± 0.01^{aA}	7.13 ± 0.01^{bB}	7.99 ± 0.01^{bA}	6.86 ± 0.01^{aB}	7.06 ± 0.02^{bA}
Third month	Oven	7.09 ± 0.03^{bB}	7.98 ± 0.02^{bA}	6.88 ± 0.00^{aB}	6.88 ± 0.00^{bB}	7.40 ± 0.01^{aB}	8.14 ± 0.00^{aA}	6.69 ± 0.02^{bB}	7.10 ± 0.01^{aA}
	Spray	7.40 ± 0.01^{aB}	8.06 ± 0.00^{aA}	6.72 ± 0.00^{bB}	6.97 ± 0.00^{aA}	7.06 ± 0.00^{bB}	7.84 ± 0.01^{bA}	6.76 ± 0.02^{aB}	6.93 ± 0.01^{bA}
Fourth month	Oven	7.18 ± 0.01^{bB}	8.16 ± 0.02^{aA}	6.58 ± 0.01^{bB}	6.84 ± 0.02^{aA}	7.24 ± 0.02^{aB}	8.03 ± 0.02^{aA}	6.69 ± 0.01^{bB}	7.04 ± 0.03^{aA}
	Spray	6.91 ± 0.01^{aB}	8.01 ± 0.01^{bA}	6.64 ± 0.00^{aB}	6.86 ± 0.01^{aA}	6.95 ± 0.01^{bB}	7.68 ± 0.01^{bA}	6.68 ± 0.00^{bB}	6.89 ± 0.04^{bA}

Values are given as mean ± SD (n=3). The different lowercase letters in the same column and different capital letters in the same row within the same storage temperature and packaging material denote a significant difference (P < 0.05) using the student's independent t-test.

A: aluminum foil packaging material; P: plastic cup packaging material; 25: storage room temperature; 38: tropical storage temperature

4.10.5. Peroxide value of whole egg powder during storage

The current study was conducted to evaluate the development of lipid oxidation through the peroxide value of WEP throughout the storage period. The escalation of peroxide value from zero day to four-months confirmed the incidence of lipid oxidation (Figure 8). The peroxide value of whole egg powder was in the range of (0.69 – 0.85) meq/kg of fat at the period (time 0) of whole egg powder production. After storage of whole egg powder for up to four months, the peroxide value of dried whole egg was reached up to 9 meq/kg of fat.

Even though the increase in terms of peroxide value was not linear for all egg powders of local and exotic breed eggs using the oven and spray drying, it was statistically significant at $P < 0.05$. Meaning, the peroxide value of whole egg powder after four months of storage was significantly different from zero day(time 0). The peroxide value of dried whole egg was increased to two month storage preiod then decreased, which was due to the increased rate of peroxide interaction (Labuza & Dugan, 1971).

The intermediate products formed during the primary oxidation of lipid oxidation will undergo degradation during the secondary oxidation. Therefore, the decrease in peroxide value of dried egg powders does not mean the decrease of lipid oxidation rather it indicates that the progress of lipid oxidation has moved to the secondary oxidation period (Velasco *et al*., 2006).

Peroxide value (PV) is one of the most used analytical indices for the quality control of fatty foods (Sun *et al*., 2011). Because, they can be considered as the first indicators of autoxidation in which they are the first molecules to be formed in the degradation process of unsaturated fatty acids (Vickers, 2017). The peroxide value of local and exotic whole egg powders was showing a significant difference irrespective of their drying methods during their storage time.

The storage condition had a statistically significant effect on the peroxide value of the whole egg powders, this will brings deterioration on the quality of lipids. Most probably this could be due to the air contained between the powder, oxidation processes were active despite the application of vacuum packaging of the powders. These results suggest that probably a better, though more expensive, packaging method would be packaging in a gas atmosphere or the atmosphere of neutral gases, e.g. nitrogen or carbon dioxide.

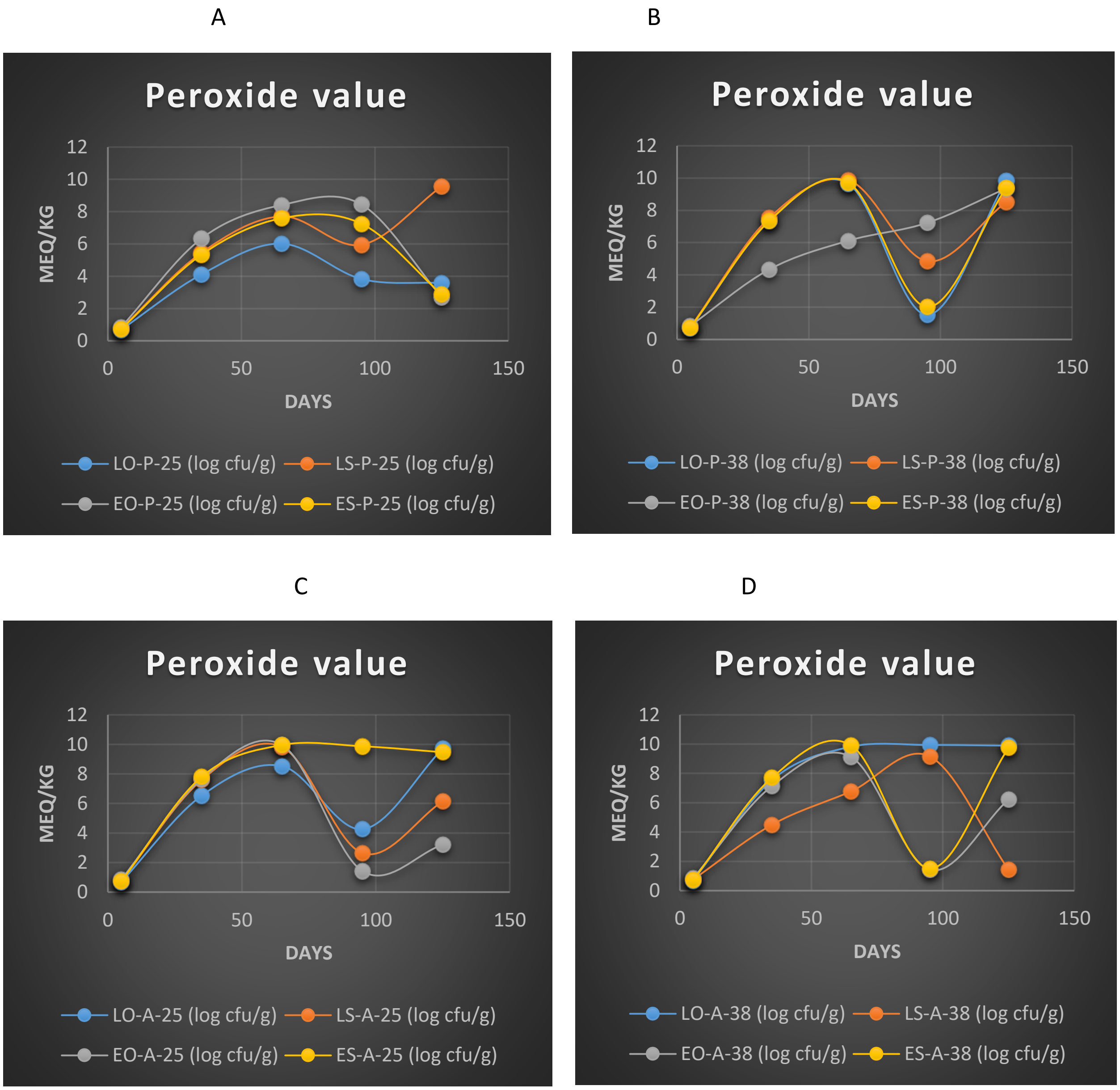


Figure 8: Peroxide value as a function of time of dried whole egg powder during storage at temperate and tropical temperatures using plastic cup and aluminum foil storage materials

4.10.6. Microbial contamination of dried egg powder

The prevalence of total aerobic mesophilic bacteria, total coliforms, and salmonella in dried WE powder was exhibited in (Tables 18 and 19) for TAMB and total coliforms. Obviously, salmonella was not presented in all samples of the dried whole eggs. Microbial contamination is caused either by ingredients or by external sources during or after processing (Degirmencioglu *et al*., 2011). It has been noted, however, that when the moisture content changed during storage, as in the work of (Gibbons and Fulton, 1943) decreases in the numbers of bacteria were found. (USDA, 2006) that, microorganisms can be found inside egg content; may be due to the fact that the egg emerges from the hens body through the same passageway feces is excreted and fecal contamination through the pores on the shell after they are laid. (Bruce and Drysdale, 1994) reported that microorganisms inside an un-cracked or whole egg may be due to the presence of pathogens within the hen's ovary or oviduct before the shell forms around the yolk and albumin.

Although an analysis of variance of the data indicated that there was a significant difference in the bacterial content of the powders with different moisture contents it is evident that much of this is due to differences in the original bacterial population of the powders. On the other hand, egg powders stored at a high temperature, the microorganisms were destroyed during storage (Thistle *et al*., 1945). However, at the same time, the quality of the powder deteriorated considerably. The microbial load of egg contents depends on temperature and length of storage, as reported by Humphrey (1994).

4.10.7. Total aerobic mesophilic bacteria of whole egg powder during storage

The effect of storage period on the total aerobic mesophilic bacteria count of whole egg powder is shown (Table 18) below. The total aerobic mesophilic bacteria of whole egg powder were in the range of (2.17 – 7.63) cfu/g for oven/spray-dried local and exotic breed dried whole eggs. The counts of TAMB in oven-dried local and exotic whole egg powders were significantly higher ($p < 0.05$) than spray-dried, local and exotic breed whole egg powders. This may be due to the higher physical contact during the drying process of the whole egg via oven drying as compared to the semi-automated spray drying of the whole egg. Even though, the water activity of both oven and spray-dried whole egg powders was in the range of 5-6 which is not more susceptible to the growth of bacteria, total aerobic mesophilic bacteria's were detected for the whole egg powders produced through oven/spray drying methods. Those TAMB might be detected because of external contaminations. Degirmencioglu *et al*., (2011) mentiond that, the external sources during or after processing and ingredients on the tested product can caused microbial contamination.

The TAMB of oven-dried local breed whole egg powders were increased along with the storage periods of temperate and tropical storage conditions stored by aluminum foil and plastic cup packaging materials. Even though, our expectation for the status of TAMB on whole egg powder during storage was increased, this has been only observed for oven-dried local breed whole egg powders along the storage period. Whereas the TAMB of spray-dried local and exotic breed whole egg powders and oven-dried exotic breed whole egg powders have not shown a linear increasing trend. This might be happened due to the decline of specific nutrients, microbial antagonistic effects of food and space, and production of metabolite products.

According to Codex, (2007);SASMO, (2007) standards, the total aerobic mesopjilic bacteria for whole egg powder had less than 100cfu/g, in which the present study was in line with this. One other thing, (Mnyandu, 2014) states on regulations governing microbiological standard for foodstuff and related matters with a focus on eggs and egg products, total mesophilic aerobic bacteria shall not exceed 20,000 colonies forming unit per gram or milliliter.

4.10.8. Total coliforms of whole egg powder during storage

Coliforms are rod shaped gram-negative non-spore forming bacteria, commonly used indicator of sanitary quality of foods Albachir, (2020). The effect of the storage period on the total coliform count of whole egg powder is shown Table 19 below. The total coliform of whole egg powder was in the range of (0.42 - 5.77) CFU/g for local breed WE powders and (0.42 – 4.06) CFU/g for exotic breed WE powders irrespective of their drying methods. However, the total coliform count of whole egg powder have not shown a linear correlation alongside the storage period, and this might be due to those different factors as stated above on the TAMB section such as the decline of specific nutrients, microbial antagonistic effects of food and space and production of metabolite products.

During the storage period of dried whole egg, the total coliforms of WE powders have shown a significant difference at $P < 0.05$ statistically between the egg types as well as the drying methods. The highest value for total coliform count was recorded at month three comparatively for both egg types and drying methods and significantly different ($P < 0.05$) from all other treatments while the least values were recorded at month two whole egg powders. The total coliform counts were higher in local breed egg than the exotic breed eggs, and this difference might be from the initial source (external contaminations) or during the analysis.

According to Codex, (2007);SASMO, (2007) standards the total coliform count for whole egg powder had less than 100cfu/g, in which the present study was in line with this. Additionaly, as Mnyandu, (2014) on Regulations governing microbiological standard for foodstuff and related matters with a focus on eggs and egg products Coliforms shall not exceed 500 per gram or milliliter of an egg product.

4.10.9. Salmonella in whole egg powder during storage

Perishable foods such as fish, eggs, meat, milk, and products of milk are highly susceptible to the growth of microorganism (Northcutt *et al*., 2004). The source of members of the Salmonella group in egg powder is not known. Keeling and Rohani, (2011) demonstrated that an organism of the typhi-murium group (salmonella strain of DT104 non DT104 cells) could survive on the eggshell when added in fecal matter and would also penetrate the egg. Accordingly, Codex, (2007) the presence of *Salmonella* and in fresh egg samples, as well as in egg powder, may be the result of contamination from the environment and personal or from the raw materials used for preparation. Salmonella was negative across all the whole egg powder treatments of day zero to four-month storage period in our present study. In support to the present study, Codex, (2007) report dictated that, in international standards salmonella spp have a zero tolerance for food for human nutrition. (Mnyandu, 2014) also stated that, *Salmonella* shall be absent in 25ml or grams of whole egg powder products.

Messens *et al*., (2005)also mentions the possibility of eggs becoming contaminated by fecal matter. Even though, according to Elkareem, (2018) report stated that over 99% of the *Salmonella* organisms in the liquid egg were killed on drying (experimental spray dryer), 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).

Table 18: Total aerobic mesophilic bacteria (log cfu/g) of whole egg powder during storage

		Total aerobic mesophilic bacteria (log_{10} cfu/g)							
Storage time	Drying method	Egg-type							
		Local				Exotic			
Time-0	Oven	3.32 ± 0.09^{bA}				4.38 ± 0.08^{bB}			
	Spray	2.42 ± 0.01^{aB}				2.17 ± 0.12^{aA}			
		P25		P38		A25		A38	
		Local	Exotic	Local	Exotic	Local	Exotic	Local	Exotic
First month	Oven	4.37 ± 0.05^{bA}	5.53 ± 0.03^{bB}	3.65 ± 0.03^{bA}	4.56 ± 0.04^{bB}	3.81 ± 0.02^{bA}	3.53 ± 0.05^{bA}	3.51 ± 0.05^{aA}	4.73 ± 0.02^{bB}
	Spray	3.56 ± 0.03^{aB}	0.38 ± 0.05^{aA}	2.66 ± 0.02a	2.46 ± 0.03a	3.53 ± 0.05^{aB}	2.41 ± 0.04^{aA}	3.52 ± 0.04^{aB}	2.66 ± 0.03^{aA}
Second month	Oven	5.11 ± 0.01^{bA}	6.62 ± 0.01^{bB}	3.90 ± 0.01^{bB}	0.85 ± 0.02^{aA}	4.92 ± 0.00^{aA}	7.63 ± 0.21^{bB}	4.11 ± 0.01^{bA}	5.47 ± 0.01^{bB}
	Spray	0.42 ± 0.10^{aA}	2.62 ± 0.01^{aB}	0.85 ± 0.02^{aA}	0.85 ± 0.02^{aA}	7.63 ± 0.21^{bB}	7.63 ± 0.21^{bB}	0.78 ± 0.03^{aA}	0.78 ± 0.03^{aA}
Third month	Oven	5.44 ± 0.01^{bA}	7.13 ± 0.04^{bB}	5.39 ± 0.01^{bB}	3.05 ± 0.01^{aA}	5.32 ± 0.00^{bB}	3.90 ± 0.01^{aA}	4.11 ± 0.01^{aA}	5.45 ± 0.01^{bB}
	Spray	5.33 ± 0.01^{aB}	4.37 ± 0.02^{aA}	3.16 ± 0.01^{aA}	4.23 ± 0.01^{bB}	3.90 ± 0.01^{aA}	4.25 ± 0.02^{bB}	4.68 ± 0.02^{bB}	4.17 ± 0.01^{aA}
Fourth month	Oven	7.05 ± 0.02^{bB}	2.86 ± 0.03^{bA}	6.44 ± 0.01^{bB}	6.37 ± 0.01^{bB}	6.77 ± 0.01^{bB}	3.43 ± 0.03^{aA}	5.67 ± 0.01^{bA}	6.87 ± 0.01^{bB}
	Spray	3.44 ± 0.02^{aB}	0.38 ± 0.05^{aA}	0.85 ± 0.02^{aA}	0.85 ± 0.02^{aA}	3.43 ± 0.03^{aA}	3.87 ± 0.01^{bB}	3.41 ± 0.02^{aB}	0.78 ± 0.03^{aA}

Values are given as mean ± SD (n=3). The different lowercase letters in the same column and different capital letters in the same row within the same storage temperature and packaging material denote a significant difference (P < 0.05) using the student's independent t-test

A: aluminum foil packaging material; P: plastic cup packaging material; 25: storage room temperature; 38: tropical storage temperature

Table 19: Total coliforms (log cfu/g) of whole egg powder during storage

		Total coliforms (log_{10} cfu/g)							
Storage time	Drying method	Egg-type							
		Local				Exotic			
Time 0	Oven	2.28 ± 0.11^{aB}				2.28 ± 0.12^{bB}			
	Spray	2.22 ± 0.16^{aA}				2.15 ± 0.05^{bA}			
		P25		P38		A25		A38	
		Local	Exotic	Local	Exotic	Local	Exotic	Local	Exotic
First month	Oven	2.62 ± 0.04^{aB}	2.48 ± 0.04^{bA}	2.77 ± 0.02^{bB}	2.46 ± 0.01^{bA}	3.63 ± 0.02^{bB}	2.37 ± 0.03^{bA}	2.54 ± 0.03^{aA}	2.57 ± 0.04^{bA}
	Spray	2.81 ± 0.02^{bB}	2.22 ± 0.04^{aA}	2.53 ± 0.03^{aB}	2.54 ± 0.03^{bB}	2.81 ± 0.03^{aB}	2.40 ± 0.03^{bA}	2.75 ± 0.02^{bB}	2.48 ± 0.07^{bA}
Second month	Oven	3.42 ± 0.01^{bB}	1.91 ± 0.01^{aA}	2.97 ± 0.02^{bB}	0.70 ± 0.03^{aA}	4.22 ± 0.01^{bB}	2.41 ± 0.01^{bA}	3.07 ± 0.02^{bB}	0.78 ± 0.03^{aA}
	Spray	0.42 ± 0.10^{aA}	2.29 ± 0.01^{bB}	0.70 ± 0.03^{aA}	0.70 ± 0.03^{aA}	0.74 ± 0.02^{aA}	0.74 ± 0.02^{aA}	0.78 ± 0.03^{aA}	0.78 ± 0.03^{aA}
Third month	Oven	3.32 ± 0.01^{bB}	2.20 ± 0.01^{aA}	5.77 ± 0.01^{bB}	1.94 ± 0.04^{aA}	4.00 ± 0.01^{bB}	2.92 ± 0.01^{aA}	3.03 ± 0.02^{aA}	3.13 ± 0.03^{aB}
	Spray	3.07 ± 0.02^{aA}	3.42 ± 0.01^{bB}	2.78 ± 0.01^{aA}	3.10 ± 0.01^{bB}	3.03 ± 0.02^{aA}	3.59 ± 0.01^{bB}	3.84 ± 0.02^{bA}	4.06 ± 0.03^{bB}
Fourth month	Oven	3.53 ± 0.02^{bB}	2.32 ± 0.00^{aA}	4.32 ± 0.01^{bB}	0.70 ± 0.03^{aA}	4.07 ± 0.01^{bB}	2.60 ± 0.01^{aA}	2.34 ± 0.01^{aA}	2.32 ± 0.01^{bA}
	Spray	0.42 ± 0.10^{aA}	0.42 ± 0.06^{bA}	0.70 ± 0.03^{aA}	0.70 ± 0.03^{aA}	2.60 ± 0.01^{aA}	2.71 ± 0.01^{bB}	2.60 ± 0.01^{bA}	0.78 ± 0.03^{aB}

Values are given as mean ± SD (n=3). The different lowercase letters in the same column and different capital letters in the same row within the same storage temperature and packaging material denote a significant difference ($P < 0.05$) using the student's independent t-test.

A: aluminum foil packaging material; P: plastic cup packaging material; 25: storage room temperature; 38: tropical storage temperature

5. Conclusion and Recommendations

5.1. Conclusion

This study concludes that whole egg powders produced by spray, and oven drying methods are generally accepted and serve as good alternatives to fresh eggs in addition to their use in the confectionery industry not compromising the final product quality. Although some differences were observed by drying method and egg type, the low moisture and water activity of the whole egg powders confirm the anticipated advantage of extending the shelf-life. The present study evaluated the effect of spray and oven-drying of local and exotic eggs on the physical, techno-functional, and nutritional composition and shelf stability of egg powders. The energy and fat content of the local eggs were significantly higher than the exotic eggs, whereas the exotic eggs had higher protein content. The spray drying of both egg types resulted in whole egg powders with optimal physical and techno-functional properties as reflected by the low water activity, > 97% yield, and high nutrient composition.

The high protein content with comparable, if not superior, protein digestibility corrected amino acid score (PDCAAS) and the high choline content that is a precursor for the synthesis of insulin-like growth hormone 1(IGF1), suggests that egg powder meet protein requirements for RUTFs and hence are ideal candidates to replace milk powder in future formulations. The oil absorption capacity and emulsion capacity also suggest the techno-functional feasibility of such replacement. However, more studies including non-inferiority clinical trials that evaluate recovery from malnutrition from egg-based RUTFs are needed. Overall acceptability of the whole egg powder from a local and exotic egg produced by oven and spray drying were ordinarily rated by the panelists. Even though, the organoleptic property of the whole egg powder was conducted for their detectable difference of the whole egg powders produced from local and exotic eggs via oven and spray drying, local breed egg powders via oven drying were highly rated than the exotic onces.

During the shelf-life study of whole egg powder, the physical, chemical, and microbial quality were evaluated starting from the initial time (time 0)to four-months of storage period. Salmonella was absent all over the storage period, whereas the TAMB and total coliforms were counted up to 7.63 and 5.77 logs CFU/g respectively. The presence of salmonella can be considered as the end of the shelf life of the whole egg powder because salmonella has a zero-tolerance for any type of food.

5.2. Recommendations

- This study was conducted only on two types of drying methods (oven and spray), but there are other drying methods which is probably more friendly for the local community. As a result, it is advisable to investigate further the capability of different drying methods on whole egg powders production.
- Since previously there are no studies specifically on local breed eggs, this needs more investigation on their specific nutritional composition and consumers acceptability.
- Whole egg powders have been utilizing by food industries for their baked products and to tracking down this, more investigations should be carried out for their shelf stability during the storage period.
- Oven drying for egg powder production is effective and can be adopted by home users as much producers as in comparison to spray drying in terms of their product quality and cost values.
- Further studies should be carried out in evaluating the nutritional value of food products made from egg powder; RUTFs and complimentary foods.
- It would be advisable to find an improved way using oxygen scavenging material in the packing of whole egg powder which may be the inclusion of these aluminum laminated packaging materials during processing. This may make it possible to decrease oxygen level entering from the external environment to food, maintaining the moisture absorbance by the hygroscopic dried powder.
- Further research is also needed on the surplus shelf life indicative parameters to explore the exact end use period of the egg powder based developed products.

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7. Annexes

Annex 1: Comparison of color values (L*a*b*) of local and exotic breed eggs during storage

S-time	Color values of whole egg powder					
	L*-value		a*-value		b*-value	
	ODLE	ODEE	ODLE	ODEE	ODLE	ODEE
Time 0	74.04 ± 0.03^{aB}	81.31 ± 0.41^{aA}	16.52 ± 0.12^{bA}	10.02 ± 0.17^{aB}	65.47 ± 0.06^{aA}	22.95 ± 0.25^{bB}
1-Month	73.73 ± 0.01^{bB}	80.08 ± 0.01^{bA}	15.17 ± 0.01^{dA}	8.95 ± 0.01^{bB}	60.57 ± 0.01^{dA}	26.30 ± 0.04^{aB}
2-Month	72.29 ± 0.02^{cB}	79.74 ± 0.38^{bcA}	16.35 ± 0.01^{cA}	9.93 ± 0.02^{aB}	65.08 ± 0.01^{bA}	22.05 ± 0.05^{cB}
4-Month	71.53 ± 0.03^{dB}	79.47 ± 0.01^{cA}	16.94 ± 0.02^{aA}	8.27 ± 0.02^{cB}	62.92 ± 0.01^{cA}	21.76 ± 0.02^{dB}
	SDLE	SDEE	SDLE	SDEE	SDLE	SDEE
Time 0	78.03 ± 0.03^{aB}	82.93 ± 0.11^{aA}	9.34 ± 0.02^{dA}	7.67 ± 0.02^{bB}	42.00 ± 0.00^{dA}	24.27 ± 0.04^{dB}
1-Month	77.36 ± 0.63^{abB}	81.61 ± 0.28^{bA}	10.66 ± 0.07^{aA}	8.34 ± 0.03^{aB}	44.18 ± 0.18^{aA}	25.04 ± 0.03^{cB}
2-Month	75.96 ± 1.66^{bcB}	80.58 ± 0.06^{cA}	9.55 ± 0.10^{cA}	7.15 ± 0.01^{cB}	42.47 ± 0.40^{cA}	25.91 ± 0.06^{aB}
4-Month	75.52 ± 0.02^{cB}	79.32 ± 0.01^{dA}	9.94 ± 0.02^{bA}	6.63 ± 0.01^{dB}	42.93 ± 0.02^{bA}	25.67 ± 0.01^{bB}

Annex 2: Comparison of color values (L*a*b*) of the oven and spray-dried eggs during storage

S-time	Color values of whole egg powder					
	L*-value		a*-value		b*-value	
	ODLE	SDLE	ODLE	SDLE	ODLE	SDLE
Time 0	74.04 ± 0.03^{aB}	78.03 ± 0.03^{aA}	16.52 ± 0.12^{bA}	9.34 ± 0.02^{dB}	65.47 ± 0.06^{aA}	42.00 ± 0.00^{dB}
1-Month	73.73 ± 0.01^{bB}	77.36 ± 0.63^{abA}	15.17 ± 0.01^{dA}	10.66 ± 0.07^{aB}	60.57 ± 0.01^{dA}	44.18 ± 0.18^{aB}
2-Month	72.29 ± 0.02^{cB}	75.96 ± 1.66^{bcA}	16.35 ± 0.01^{cA}	9.55 ± 0.10^{cB}	65.08 ± 0.01^{bA}	42.47 ± 0.40^{cB}
4-Month	71.53 ± 0.03^{dB}	75.52 ± 0.02^{cA}	16.94 ± 0.02^{aA}	9.94 ± 0.02^{bB}	62.92 ± 0.01^{cA}	42.93 ± 0.02^{bB}
	ODEE	SDEE	ODEE	SDEE	ODEE	ODEE
Time 0	81.31 ± 0.41^{aB}	82.93 ± 0.11^{aA}	10.02 ± 0.17^{aA}	7.67 ± 0.02^{bB}	22.95 ± 0.25^{bB}	24.27 ± 0.04^{dA}
1-Month	80.08 ± 0.01^{bB}	81.61 ± 0.28^{bA}	8.95 ± 0.01^{bA}	8.34 ± 0.03^{aB}	26.30 ± 0.04^{aA}	25.04 ± 0.03^{cB}
2-Month	79.74 ± 0.38^{bcB}	80.58 ± 0.06^{cA}	9.93 ± 0.02^{aA}	7.15 ± 0.01^{cB}	22.05 ± 0.05^{cB}	25.91 ± 0.06^{aA}
4-Month	79.47 ± 0.01^{cA}	79.32 ± 0.01^{dB}	8.27 ± 0.02^{cA}	6.63 ± 0.01^{dB}	21.76 ± 0.02^{dB}	25.67 ± 0.01^{bA}

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

Annex 3: Moisture content of local breed oven and spray-dried egg during storage

	Moisture content (g/100g)							
Time 0	$3.63 \pm .02^{dB}$	$2.56 \pm .09^{aA}$	$3.63 \pm .02^{bcB}$	$2.56 \pm .09^{bA}$	$3.63 \pm .02^{aB}$	$2.56 \pm .09^{aA}$	$3.63 \pm .02^{cB}$	$2.56 \pm .09^{aA}$
	HO-P-25	HS-P-25	HO-P-38	HS-P-38	HO-A-25	HS-A-25	HO-A-38	HS-A-38
1-Month	$4.21 \pm .13^{eB}$	$3.38 \pm .03^{dA}$	$4.55 \pm .58^{aB}$	$3.36 \pm .04^{cA}$	$5.19 \pm .05^{bA}$	$5.46 \pm .00^{cB}$	$3.17 \pm .03^{bB}$	$3.09 \pm .01^{cA}$
2-Month	$3.23 \pm .01^{bB}$	$3.00 \pm .01^{cA}$	$3.19 \pm .01^{bB}$	$2.79 \pm .00^{bA}$	$5.41 \pm .00^{bB}$	$5.06 \pm .00^{bA}$	$2.54 \pm .00^{aA}$	$2.59 \pm .00^{aB}$
3-Month	$2.72 \pm .00^{aA}$	$2.75 \pm .00^{bB}$	$2.55 \pm .00^{aB}$	$1.69 \pm .00^{aA}$	$6.83 \pm .00^{cB}$	$5.98 \pm .00^{dA}$	$3.13 \pm .00^{bB}$	$2.97 \pm .00^{bA}$
4-Month	$3.38 \pm .01^{cA}$	$5.48 \pm .16^{eB}$	$3.74 \pm .25^{cB}$	$2.69 \pm .52^{bA}$	$6.67 \pm .59^{cB}$	$6.37 \pm .45^{eB}$	$3.94 \pm .18^{dB}$	$3.84 \pm .02^{dB}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference ($P < 0.05$) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference ($P < 0.05$) using the student's independent t-test

Annex 4: Moisture content of exotic breed oven and spray-dried egg during storage

	Moisture content (g/100g)							
Time 0	$4.25 \pm .05^{bB}$	$3.39 \pm .03^{eA}$	$4.25 \pm .05^{bB}$	$3.39 \pm .03^{cA}$	$4.25 \pm .05^{aB}$	$3.39 \pm .03^{aA}$	$4.25 \pm .05^{dB}$	$3.39 \pm .03^{cA}$
	FO-P-25	FS-P-25	FO-P-38	FS-P-38	FO-A-25	FS-A-25	FO-A-38	FS-A-38
1-Month	$5.65 \pm .05^{eB}$	$3.14 \pm .02^{cA}$	$5.29 \pm .05^{cB}$	$3.21 \pm .05^{cA}$	$6.63 \pm .06^{cB}$	$5.44 \pm .03^{bA}$	$3.83 \pm .03^{cB}$	$3.08 \pm .02^{aA}$
2-Month	$5.12 \pm .03^{cB}$	$3.18 \pm .01^{dA}$	$4.38 \pm .01^{bB}$	$2.65 \pm .01^{bA}$	$5.94 \pm .00^{bB}$	$5.77 \pm .02^{bA}$	$3.30 \pm .01^{aB}$	$3.14 \pm .01^{aA}$
3-Month	$4.08 \pm .00^{aB}$	$2.12 \pm .00^{aA}$	$3.44 \pm .00^{aB}$	$1.66 \pm .00^{aA}$	$7.25 \pm .00^{dB}$	$6.55 \pm .00^{cA}$	$3.51 \pm .00^{bB}$	$3.27 \pm .00^{bA}$
4-Month	$5.42 \pm .04^{dB}$	$3.03 \pm .18^{bA}$	$5.09 \pm .54^{cB}$	$3.58 \pm .55^{cA}$	$7.48 \pm .40^{dB}$	$7.04 \pm .53^{dB}$	$4.35 \pm .13^{dA}$	$4.71 \pm .07^{dB}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference ($P < 0.05$) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference ($P < 0.05$) using the student's independent t-test

Annex 5: Moisture content of oven-dried local and exotic breed whole egg powder during storage

	Moisture content (g/100g)							
Time 0	$3.63 \pm .02^{dB}$	$4.25 \pm .05^{bB}$	$3.63 \pm .02^{bcB}$	$4.25 \pm .05^{bB}$	$3.63 \pm .02^{aB}$	$4.25 \pm .05^{aB}$	$3.63 \pm .02^{cB}$	$4.25 \pm .05^{dB}$
	HO-P-25	FO-P-25	HO-P-38	FO-P-38	HO-A-25	FO-A-25	HO-A-38	FO-A-38
1-Month	$4.21 \pm .13^{eB}$	$5.65 \pm .05^{eB}$	$4.55 \pm .58^{aB}$	$5.29 \pm .05^{cB}$	$5.19 \pm .05^{bA}$	$6.63 \pm .06^{cB}$	$3.17 \pm .03^{bB}$	$3.83 \pm .03^{cB}$
2-Month	$3.23 \pm .01^{bB}$	$5.12 \pm .03^{cB}$	$3.19 \pm .01^{bB}$	$4.38 \pm .01^{bB}$	$5.41 \pm .00^{bB}$	$5.94 \pm .00^{bB}$	$2.54 \pm .00^{aA}$	$3.30 \pm .01^{aB}$
3-Month	$2.72 \pm .00^{aA}$	$4.08 \pm .00^{aB}$	$2.55 \pm .00^{aB}$	$3.44 \pm .00^{aB}$	$6.83 \pm .00^{cB}$	$7.25 \pm .00^{dB}$	$3.13 \pm .00^{bB}$	$3.51 \pm .00^{bB}$
4-Month	$3.38 \pm .01^{cA}$	$5.42 \pm .04^{dB}$	$3.74 \pm .25^{cB}$	$5.09 \pm .54^{cB}$	$6.67 \pm .59^{cB}$	$7.48 \pm .40^{dB}$	$3.94 \pm .18^{dB}$	$4.35 \pm .13^{dA}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference ($P < 0.05$) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference ($P < 0.05$) using the student's independent t-test

Annex 6: Moisture content of spray-dried local and exotic breed whole egg powder during storage

	Moisture content (g/100g)							
Time 0	$2.56 \pm .09^{aA}$	$3.39 \pm .03^{eA}$	$2.56 \pm .09^{bA}$	$3.39 \pm .03^{cA}$	$2.56 \pm .09^{aA}$	$3.39 \pm .03^{aA}$	$2.56 \pm .09^{aA}$	$3.39 \pm .03^{cA}$
	HS-P-25	FS-P-25	HS-P-38	FS-P-38	HS-A-25	FS-A-25	HS-A-38	FS-A-38
1-Month	$3.38 \pm .03^{dA}$	$3.14 \pm .02^{cA}$	$3.36 \pm .04^{cA}$	$3.21 \pm .05^{cA}$	$5.46 \pm .00^{cB}$	$5.44 \pm .03^{bA}$	$3.09 \pm .01^{cA}$	$3.08 \pm .02^{aA}$
2-Month	$3.00 \pm .01^{cA}$	$3.18 \pm .01^{dA}$	$2.79 \pm .00^{bA}$	$2.65 \pm .01^{bA}$	$5.06 \pm .00^{bA}$	$5.77 \pm .02^{bA}$	$2.59 \pm .00^{aB}$	$3.14 \pm .01^{aA}$
3-Month	$2.75 \pm .00^{bB}$	$2.12 \pm .00^{aA}$	$1.69 \pm .00^{aA}$	$1.66 \pm .00^{aA}$	$5.98 \pm .00^{dA}$	$6.55 \pm .00^{cA}$	$2.97 \pm .00^{bA}$	$3.27 \pm .00^{bA}$
4-Month	$5.48 \pm .16^{eB}$	$3.03 \pm .18^{bA}$	$2.69 \pm .52^{bA}$	$3.58 \pm .55^{cA}$	$6.37 \pm .45^{eB}$	$7.04 \pm .53^{dB}$	$3.84 \pm .02^{dB}$	$4.71 \pm .07^{dB}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

Annex 7: Water activity of local breed oven and spray-dried egg during storage

	Water activity (g/100g)							
Time 0	$0.47 \pm .00^{bB}$	$0.44 \pm .01^{aA}$	$0.47 \pm .00^{aB}$	$0.44 \pm .01^{aA}$	$0.47 \pm .00^{aB}$	$0.44 \pm .01^{aA}$	$0.47 \pm .00^{bB}$	$0.44 \pm .01^{aA}$
	HO-P-25	HS-P-25	HO-P-38	HS-P-38	HO-A-25	HS-A-25	HO-A-38	HS-A-38
1-Month	$0.50 \pm .00^{cB}$	$0.50 \pm .00^{bB}$	$0.52 \pm .01^{bB}$	$0.49 \pm .01^{cA}$	$0.54 \pm .01^{bB}$	$0.57 \pm .02^{bB}$	$0.53 \pm .01^{eB}$	$0.49 \pm .01^{dA}$
2-Month	$0.50 \pm .00^{cA}$	$0.53 \pm .01^{cB}$	$0.53 \pm .01^{cB}$	$0.51 \pm .01^{dA}$	$0.59 \pm .02^{cB}$	$0.60 \pm .01^{cB}$	$0.51 \pm .01^{dB}$	$0.47 \pm .01^{cA}$
3-Month	$0.52 \pm .01^{dA}$	$0.56 \pm .00^{dB}$	$0.54 \pm .01^{dB}$	$0.50 \pm .01^{cdA}$	$0.66 \pm .01^{eB}$	$0.64 \pm .01^{dA}$	$0.49 \pm .01^{cA}$	$0.47 \pm .02^{bA}$
4-Month	$0.47 \pm .02^{aA}$	$0.57 \pm .01^{dB}$	$0.47 \pm .01^{aA}$	$0.46 \pm .01^{bA}$	$0.61 \pm .01^{dB}$	$0.62 \pm .01^{cB}$	$0.4 6\pm .01^{aA}$	$0.48 \pm .01^{cA}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

Annex 8: Water activity of exotic breed oven and spray-dried egg during storage

	Water activity (g/100g)							
Time 0	$0.48 \pm .02^{aA}$	$0.46 \pm .00^{bA}$	$0.48 \pm .02^{aB}$	$0.46 \pm .00^{aA}$	$0.48 \pm .02^{aB}$	$0.46 \pm .00^{aA}$	$0.49 \pm .02^{bA}$	$0.46 \pm .00^{bA}$
	FO-P-25	FS-P-25	FO-P-38	FS-P-38	FO-A-25	FS-A-25	FO-A-38	FS-A-38
1-Month	$0.57 \pm .00^{dB}$	$0.49 \pm .01^{dA}$	$0.57 \pm .01^{dB}$	$0.52 \pm .01^{cA}$	$0.58 \pm .01^{bB}$	$0.54 \pm .01^{bA}$	$0.51 \pm .01^{cB}$	$0.51 \pm .00^{eB}$
2-Month	$0.56 \pm .01^{bB}$	$0.48 \pm .02^{cdA}$	$0.54 \pm .01^{cB}$	$0.51 \pm .01^{cA}$	$0.63 \pm .01^{cB}$	$0.60 \pm .02^{cB}$	$0.49 \pm .01^{bA}$	$0.50 \pm .00^{dB}$
3-Month	$0.56 \pm .02^{bcB}$	$0.47 \pm .03^{cA}$	$0.53 \pm .01^{bB}$	$0.52 \pm .01^{cB}$	$0.65 \pm .01^{dB}$	$0.63 \pm .01^{dB}$	$0.48 \pm .01^{aA}$	$0.49 \pm .02^{cA}$
4-Month	$0.55 \pm .03^{bcB}$	$0.44 \pm .01^{aA}$	$0.56 \pm .01^{dB}$	$0.50 \pm .01^{bA}$	$0.64 \pm .01^{dB}$	$0.63 \pm .01^{dB}$	$0.49 \pm .01^{bA}$	$0.45 \pm .02^{aA}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

Annex 9: Water activity of oven-dried local and exotic breed whole egg powder during storage

	Water activity (g/100g)							
Time 0	$0.47 \pm .00^{bB}$	$0.48 \pm .02^{aA}$	$0.47 \pm .00^{aB}$	$0.48 \pm .02^{aB}$	$0.47 \pm .00^{aB}$	$0.48 \pm .02^{aB}$	$0.47 \pm .00^{bB}$	$0.49 \pm .02^{bA}$
	HO-P-25	FO-P-25	HO-P-38	FO-P-38	HO-A-25	FO-A-25	HO-A-38	FO-A-38
1-Month	$0.50 \pm .00^{cB}$	$0.57 \pm .00^{dB}$	$0.52 \pm .01^{bB}$	$0.57 \pm .01^{dB}$	$0.54 \pm .01^{bB}$	$0.58 \pm .01^{bB}$	$0.53 \pm .01^{eB}$	$0.51 \pm .01^{cB}$
2-Month	$0.50 \pm .00^{cA}$	$0.56 \pm .01^{bB}$	$0.53 \pm .01^{cB}$	$0.54 \pm .01^{cB}$	$0.59 \pm .02^{cB}$	$0.63 \pm .01^{cB}$	$0.51 \pm .01^{dB}$	$0.49 \pm .01^{bA}$
3-Month	$0.52 \pm .01^{dA}$	$0.56 \pm .02^{bcB}$	$0.54 \pm .01^{dB}$	$0.53 \pm .01^{bB}$	$0.66 \pm .01^{eB}$	$0.65 \pm .01^{dB}$	$0.49 \pm .01^{cA}$	$0.48 \pm .01^{aA}$
4-Month	$0.47 \pm .02^{aA}$	$0.55 \pm .03^{bcB}$	$0.47 \pm .01^{aA}$	$0.56 \pm .01^{dB}$	$0.61 \pm .01^{dB}$	$0.64 \pm .01^{dB}$	$0.4\ 6\pm .01^{aA}$	$0.49 \pm .01^{bA}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

Annex 10: Water activity of spray-dried local and exotic breed whole egg powder during storage

	Water activity (g/100g)							
Time 0	$0.44 \pm .01^{aA}$	$0.46 \pm .00^{bA}$	$0.44 \pm .01^{aA}$	$0.46 \pm .00^{aA}$	$0.44 \pm .01^{aA}$	$0.46 \pm .00^{aA}$	$0.44 \pm .01^{aA}$	$0.46 \pm .00^{bA}$
	HS-P-25	FS-P-25	HS-P-38	FS-P-38	HS-A-25	FS-A-25	HS-A-38	FS-A-38
1-Month	$0.50 \pm .00^{bB}$	$0.49 \pm .01^{dA}$	$0.49 \pm .01^{cA}$	$0.52 \pm .01^{cA}$	$0.57 \pm .02^{bB}$	$0.54 \pm .01^{bA}$	$0.49 \pm .01^{dA}$	$0.51 \pm .00^{eB}$
2-Month	$0.53 \pm .01^{cB}$	$0.48 \pm .02^{cdA}$	$0.51 \pm .01^{dA}$	$0.51 \pm .01^{cA}$	$0.60 \pm .01^{cB}$	$0.60 \pm .02^{cB}$	$0.47 \pm .01^{cA}$	$0.50 \pm .00^{dB}$
3-Month	$0.56 \pm .00^{dB}$	$0.47 \pm .03^{cA}$	$0.50 \pm .01^{cdA}$	$0.52 \pm .01^{cB}$	$0.64 \pm .01^{dA}$	$0.63 \pm .01^{dB}$	$0.47 \pm .02^{bA}$	$0.49 \pm .02^{cA}$
4-Month	$0.57 \pm .01^{dB}$	$0.44 \pm .01^{aA}$	$0.46 \pm .01^{bA}$	$0.50 \pm .01^{bA}$	$0.62 \pm .01^{cB}$	$0.63 \pm .01^{dB}$	$0.48 \pm .01^{cA}$	$0.45 \pm .02^{aA}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

Annex 11: pH value of local breed oven and spray-dried egg during storage

	pH (g/100g)							
Time 0	$7.46 \pm .03^{aB}$	$7.76 \pm .01^{aA}$	$7.46 \pm .03^{aB}$	$7.76 \pm .01^{aA}$	$7.46 \pm .03^{aB}$	$7.76 \pm .01^{aA}$	$7.46 \pm .03^{aB}$	$7.76 \pm .01^{aA}$
	HO-P-25	HS-P-25	HO-P-38	HS-P-38	HO-A-25	HS-A-25	HO-A-38	HS-A-38
1-Month	$7.15 \pm .03^{bB}$	$7.60 \pm .01^{bA}$	$7.07 \pm .01^{bB}$	$7.13 \pm .00^{bA}$	$7.19 \pm .02^{eB}$	$7.22 \pm .00^{bA}$	$6.87 \pm .02^{bB}$	$7.07 \pm .02^{bA}$
2-Month	$7.17 \pm .00^{bB}$	$7.58 \pm .02^{cA}$	$6.71 \pm .01^{dB}$	$6.86 \pm .01^{cA}$	$7.29 \pm .01^{cA}$	$7.13 \pm .01^{cB}$	$6.72 \pm .02^{cB}$	$6.86 \pm .01^{cA}$
3-Month	$7.09 \pm .03^{cB}$	$7.40 \pm .01^{dA}$	$6.88 \pm .00^{cA}$	$6.72 \pm .00^{dB}$	$7.40 \pm .01^{bA}$	$7.06 \pm .00^{dB}$	$6.69 \pm .02^{cB}$	$6.76 \pm .02^{dA}$
4-Month	$7.18 \pm .01^{bA}$	$6.91 \pm .01^{eB}$	$6.58 \pm .01^{eB}$	$6.64 \pm .00^{eA}$	$7.24 \pm .02^{dA}$	$6.95 \pm .01^{eB}$	$6.69 \pm .01^{cB}$	$6.68 \pm .00^{eB}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

Annex 12: pH value of exotic breed oven and spray-dried egg during storage

	pH (g/100g)							
Time 0	$8.62 \pm .01^{aA}$	$8.53 \pm .00^{aB}$	$8.62 \pm .01^{aA}$	$8.53 \pm .00^{aB}$	$8.62 \pm .01^{aA}$	$8.53 \pm .00^{aB}$	$8.62 \pm .01^{aA}$	$8.53 \pm .00^{aB}$
	FO-P-25	FS-P-25	FO-P-38	FS-P-38	FO-A-25	FS-A-25	FO-A-38	FS-A-38
1-Month	$8.17 \pm .01^{bA}$	$8.11 \pm .01^{bB}$	$7.36 \pm .01^{bB}$	$7.54 \pm .01^{bA}$	$8.33 \pm .01^{bA}$	$8.24 \pm .02^{bB}$	$7.68 \pm .01^{bA}$	$7.51 \pm .01^{bB}$
2-Month	$8.18 \pm .01^{bA}$	$8.09 \pm .00^{cB}$	$7.05 \pm .02^{cB}$	$7.09 \pm .01^{cA}$	$8.17 \pm .06^{cA}$	$7.99 \pm .01^{cB}$	$7.24 \pm .02^{cA}$	$7.06 \pm .02^{cB}$
3-Month	$7.98 \pm .02^{cB}$	$8.06 \pm .00^{dA}$	$6.88 \pm .00^{dB}$	$6.97 \pm .00^{dA}$	$8.14 \pm .00^{cA}$	$7.84 \pm .01^{dB}$	$7.10 \pm .01^{dA}$	$6.93 \pm .01^{dB}$
4-Month	$8.16 \pm .02^{bA}$	$8.01 \pm .01^{eB}$	$6.84 \pm .02^{eB}$	$6.86 \pm .01^{eB}$	$8.03 \pm .02^{dA}$	$7.68 \pm .01^{eB}$	$7.04 \pm .03^{eA}$	$6.89 \pm .04^{eB}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

Annex 13: pH value of oven-dried local and exotic breed whole egg powder during storage

	pH (g/100g)							
Time 0	$7.46 \pm .03^{aB}$	$8.62 \pm .01^{aA}$	$7.46 \pm .03^{aB}$	$8.62 \pm .01^{aA}$	$7.46 \pm .03^{aB}$	$8.62 \pm .01^{aA}$	$7.46 \pm .03^{aB}$	$8.62 \pm .01^{aA}$
	HO-P-25	FO-P-25	HO-P-38	FO-P-38	HO-A-25	FO-A-25	HO-A-38	FO-A-38
1-Month	$7.15 \pm .03^{bB}$	$8.17 \pm .01^{bA}$	$7.07 \pm .01^{bB}$	$7.36 \pm .01^{bB}$	$7.19 \pm .02^{eB}$	$8.33 \pm .01^{bA}$	$6.87 \pm .02^{bB}$	$7.68 \pm .01^{bA}$
2-Month	$7.17 \pm .00^{bB}$	$8.18 \pm .01^{bA}$	$6.71 \pm .01^{dB}$	$7.05 \pm .02^{cB}$	$7.29 \pm .01^{cA}$	$8.17 \pm .06^{cA}$	$6.72 \pm .02^{cB}$	$7.24 \pm .02^{cA}$
3-Month	$7.09 \pm .03^{cB}$	$7.98 \pm .02^{cB}$	$6.88 \pm .00^{cA}$	$6.88 \pm .00^{dB}$	$7.40 \pm .01^{bA}$	$8.14 \pm .00^{cA}$	$6.69 \pm .02^{cB}$	$7.10 \pm .01^{dA}$
4-Month	$7.18 \pm .01^{bA}$	$8.16 \pm .02^{bA}$	$6.58 \pm .01^{eB}$	$6.84 \pm .02^{eB}$	$7.24 \pm .02^{dA}$	$8.03 \pm .02^{dA}$	$6.69 \pm .01^{cB}$	$7.04 \pm .03^{eA}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

Annex 14: pH value of spray-dried local and exotic breed whole egg powder during storage

	pH (g/100g)							
Time 0	$7.76 \pm .01^{aA}$	$8.53 \pm .00^{aB}$	$7.76 \pm .01^{aA}$	$8.53 \pm .00^{aB}$	$7.76 \pm .01^{aA}$	$8.53 \pm .00^{aB}$	$7.76 \pm .01^{aA}$	$8.53 \pm .00^{aB}$
	HS-P-25	FS-P-25	HS-P-38	FS-P-38	HS-A-25	FS-A-25	HS-A-38	FS-A-38
1-Month	$7.60 \pm .01^{bA}$	$8.11 \pm .01^{bB}$	$7.13 \pm .00^{bA}$	$7.54 \pm .01^{bA}$	$7.22 \pm .00^{bA}$	$8.24 \pm .02^{bB}$	$7.07 \pm .02^{bA}$	$7.51 \pm .01^{bB}$
2-Month	$7.58 \pm .02^{cA}$	$8.09 \pm .00^{cB}$	$6.86 \pm .01^{cA}$	$7.09 \pm .01^{cA}$	$7.13 \pm .01^{cB}$	$7.99 \pm .01^{cB}$	$6.86 \pm .01^{cA}$	$7.06 \pm .02^{cB}$
3-Month	$7.40 \pm .01^{dA}$	$8.06 \pm .00^{dA}$	$6.72 \pm .00^{dB}$	$6.97 \pm .00^{dA}$	$7.06 \pm .00^{dB}$	$7.84 \pm .01^{dB}$	$6.76 \pm .02^{dA}$	$6.93 \pm .01^{dB}$
4-Month	$6.91 \pm .01^{eB}$	$8.01 \pm .01^{eB}$	$6.64 \pm .00^{eA}$	$6.86 \pm .01^{eB}$	$6.95 \pm .01^{eB}$	$7.68 \pm .01^{eB}$	$6.68 \pm .00^{eB}$	$6.89 \pm .04^{eB}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

Annex 15: Peroxide value of local breed oven and spray-dried egg during storage

	Peroxide value (g/100g)							
Time 0	$0.69 \pm .01^{aA}$	$0.76 \pm .02^{aB}$	$0.69 \pm .01^{aA}$	$0.76 \pm .02^{aB}$	$0.69 \pm .01^{aA}$	$0.76 \pm .02^{aB}$	$0.69 \pm .01^{aA}$	$0.76 \pm .02^{aB}$
	HO-P-25	HS-P-25	HO-P-38	HS-P-38	HO-A-25	HS-A-25	HO-A-38	HS-A-38
1-Month	$4.11 \pm .05^{dA}$	$5.45 \pm .23^{bB}$	$7.35 \pm .08^{cB}$	$7.53 \pm .24^{cA}$	$6.53 \pm .22^{cA}$	$7.59 \pm .13^{dB}$	$7.55 \pm .26^{bB}$	$4.50 \pm .12^{cA}$
2-Month	$6.02 \pm .01^{eA}$	$7.71 \pm .01^{dB}$	$9.65 \pm .02^{dA}$	$9.87 \pm .02^{eB}$	$8.53 \pm .02^{dA}$	$9.82 \pm .01^{eB}$	$9.82 \pm .01^{cB}$	$6.77 \pm .02^{dA}$
3-Month	$3.83 \pm .02^{cA}$	$5.95 \pm .03^{cB}$	$1.53 \pm .02^{bA}$	$4.85 \pm .02^{bB}$	$4.26 \pm .01^{bB}$	$2.64 \pm .01^{bA}$	$9.94 \pm .02^{cB}$	$9.16 \pm .02^{eA}$
4-Month	$3.58 \pm .01^{bA}$	$9.57 \pm .06^{eB}$	$9.84 \pm .02^{eB}$	$8.52 \pm .01^{dA}$	$9.72 \pm .01^{eB}$	$6.15 \pm .01^{cA}$	$9.90 \pm .03^{cB}$	$1.42 \pm .01^{bA}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

Annex 16: Peroxide value of exotic breed oven and spray-dried egg during storage

	Peroxide value (g/100g)							
Time 0	$0.85 \pm .04^{aB}$	$0.73 \pm .01^{aA}$	$0.85 \pm .04^{aB}$	$0.73 \pm .01^{aA}$	$0.85 \pm .04^{aB}$	$0.73 \pm .01^{aA}$	$0.85 \pm .04^{aB}$	$0.73 \pm .01^{aA}$
	FO-P-25	FS-P-25	FO-P-38	FS-P-38	FO-A-25	FS-A-25	FO-A-38	FS-A-38
1-Month	$6.33 \pm .07^{cB}$	$5.33 \pm .18^{cA}$	$4.34 \pm .32^{bA}$	$7.34 \pm .29^{cB}$	$7.67 \pm .17^{dB}$	$7.81 \pm .13^{bB}$	$7.14 \pm .13^{dB}$	$7.71 \pm .35^{cB}$
2-Month	$8.41 \pm .04^{dB}$	$7.59 \pm .05^{eA}$	$6.12 \pm .16^{cA}$	$9.72 \pm .01^{eB}$	$9.95 \pm .02^{eB}$	$9.96 \pm .02^{dB}$	$9.13 \pm .02^{eA}$	$9.93 \pm .02^{dB}$
3-Month	$8.44 \pm .02^{dB}$	$7.25 \pm .04^{dA}$	$7.23 \pm .02^{dB}$	$2.02 \pm .01^{bA}$	$1.42 \pm .01^{bA}$	$9.87 \pm .01^{dB}$	$1.43 \pm .05^{bA}$	$1.51 \pm .04^{bA}$
4-Month	$2.71 \pm .02^{bA}$	$2.88 \pm .03^{bB}$	$9.36 \pm .02^{eB}$	$9.42 \pm .01^{dB}$	$3.21 \pm .01^{cA}$	$9.47 \pm .01^{cB}$	$6.23 \pm .02^{cA}$	$9.77 \pm .02^{dB}$

Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

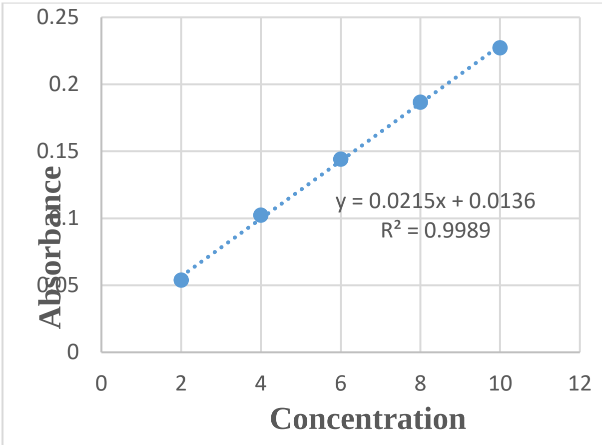
Annex 17: Peroxide value of oven-dried local and exotic breed whole egg powder during storage

	Peroxide value (g/100g)							
Time 0	$0.69 \pm .01^{aA}$	$0.85 \pm .04^{aB}$	$0.69 \pm .01^{aA}$	$0.85 \pm .04^{aB}$	$0.69 \pm .01^{aA}$	$0.85 \pm .04^{aB}$	$0.69 \pm .01^{aA}$	$0.85 \pm .04^{aB}$
	HO-P-25	FO-P-25	HO-P-38	FO-P-38	HO-A-25	FO-A-25	HO-A-38	FO-A-38
1-Month	$4.11 \pm .05^{dA}$	$6.33 \pm .07^{cB}$	$7.35 \pm .08^{cB}$	$4.34 \pm .32^{bA}$	$6.53 \pm .22^{cA}$	$7.67 \pm .17^{dB}$	$7.55 \pm .26^{bB}$	$7.14 \pm .13^{dB}$
2-Month	$6.02 \pm .01^{eA}$	$8.41 \pm .04^{dB}$	$9.65 \pm .02^{dB}$	$6.12 \pm .16^{cA}$	$8.53 \pm .02^{dA}$	$9.95 \pm .02^{eB}$	$9.82 \pm .01^{cB}$	$9.13 \pm .02^{eA}$
3-Month	$3.83 \pm .02^{cB}$	$8.44 \pm .02^{dB}$	$1.53 \pm .02^{bA}$	$7.23 \pm .02^{dB}$	$4.26 \pm .01^{bB}$	$1.42 \pm .01^{bA}$	$9.94 \pm .02^{cB}$	$1.43 \pm .05^{bA}$
4-Month	$3.58 \pm .01^{bB}$	$2.71 \pm .02^{bA}$	$9.84 \pm .02^{eB}$	$9.36 \pm .02^{eB}$	$9.72 \pm .01^{eB}$	$3.21 \pm .01^{cA}$	$9.90 \pm .03^{cB}$	$6.23 \pm .02^{cA}$

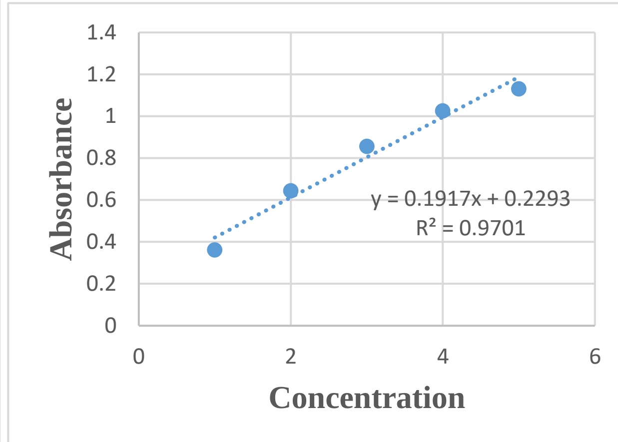
Values are given as mean ± SE (n=3). The different lowercase letters in the same column denote a significant difference (P < 0.05) using Duncan new multiple range test and different capital letters in the same row within the same parameter denote a significant difference (P < 0.05) using the student's independent t-test

Annex 18: **Calibration curve for minerals (Ca, K, Mg, Na, P, Fe, Zn)**

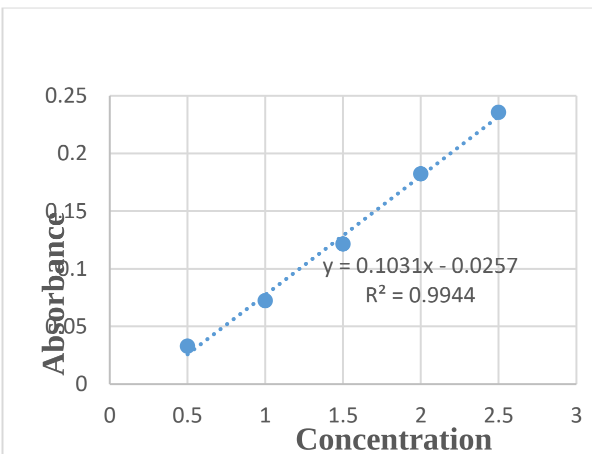
Calcium (mg/l)



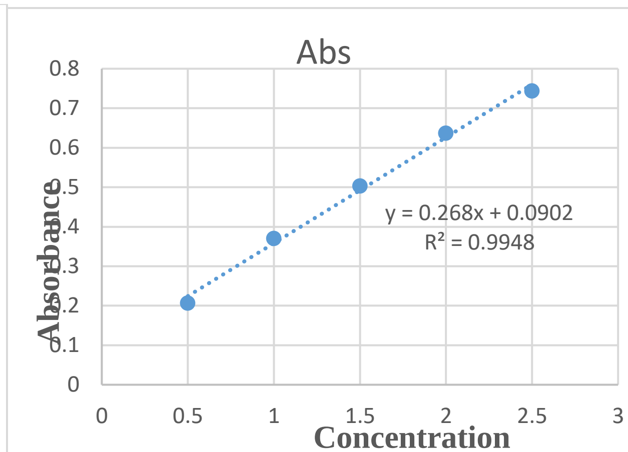
Magnesium (mg/l)



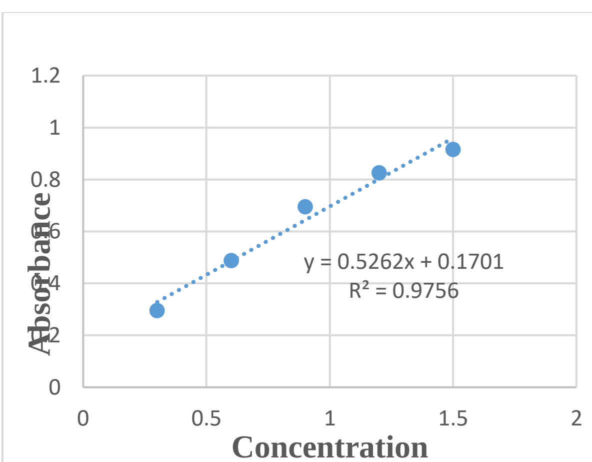
Potassium (mg/l)



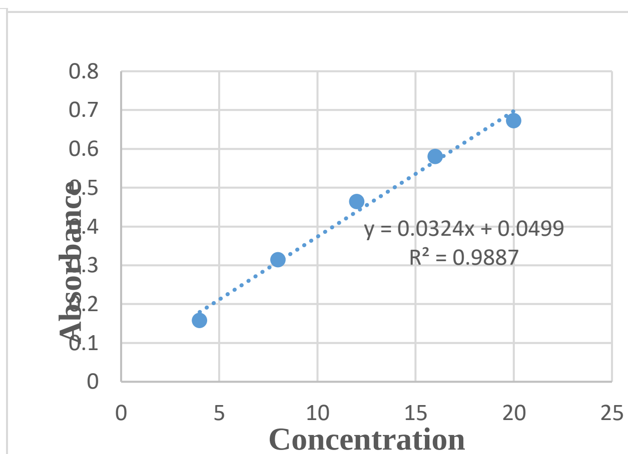
Sodium (mg/l)



Iron (mg/l)



Zinc (mg/l)



Annex 19: **Sensory Evaluation Ballot for Egg Powder**

Panelist: -______________________________ Date: -____________________

Instructions:

Please look at and test each sample of egg powder order from left to right or right to left as shown on the ballot. Indicate how much you like or dislike each sample by checking the appropriate phrase of category which is listed below and mark your choice with the number that corresponds to your preference on each parameter. Please rinse your mouth before and after testing each sample.

Code	Appearance/ ቅረፅ	Color /ቀለም/	/Aroma/ መዓዛ	/Taste/ ጣዕም	/Texture/ የአካል ቅንጣቶች ንብር	/Overall Acceptability/ አጠቃላይ ሁኔታ
463						
219						
662						
995						

Seven-point hedonic scale: **- 7**-like very much, **6**-like moderately, **5**-like slightly, **4**-neither like nor dislike, **3-**dislike slightly, **2-**dislike moderately, **1-**dislike very much

3. Comment

/አስተያየት/: ____

4. Signature /ፊርማ/: ______________________________

Thank you in advance for your valuable contribution