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REVIEW

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Nutritional Benefits of Eggs: Understanding their Importance in Human Health

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Conflict of Interest

The authors declare that the manuscript was formulated in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Authors Contribution

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Abstract

Nutritional deficiency in the diet constitutes a major challenge for human health and well-being. In order to overcome this issue, poultry products such as eggs and meat serves as an important part of the human diet, it supplies the required amount of balanced nutrients (protein) needed for body growth and metabolism. The poultry industry includes broiler and layer production. However, the layer industry is well organized. Globally egg producers and consumer's usage has grown due to the fact that eggs are easily available and affordable animal protein in the consumer markets. Increased egg production and consumption (as per the recommended standards) will greatly enhance the dietary needs of both the growing infants and adults. In this article, we will discuss about global production, consumption, structural composition, nutritious content, and health benefits of chicken eggs.

KEYWORDS

Poultry Egg, Production, Composition, Nutritious Source, Deficiency, Human Health.

INTRODUCTION

Worldwide egg production is increased by 68% from 2000 to 2020, it is increased from 51 million tonnes to 86 million tonnes (with an average growth of 3% annually). In the poultry sector, 92 – 93% of the world's eggs are being produced by chickens. Asia accounted for 62.1% of the world's output in egg production, followed by the Americas (20.6%), Europe (12.9%), Africa (4%), and Oceania (0.4%) respectively (FAO,2022). The term "total egg production in the shell" refers to the total number of eggs produced by all varieties of hens across both the conventional sectors (small farms owned by individual producers) and the modern industries (massive, intensive commercial poultry farms). Eggs used for hatcheries are also included in the total output and excluding farm waste (FAO, 2022). In total egg production, China stands first with 603 billion eggs produced, followed by USA and India. Netherlands is the major egg exporter with 351,223 tonnes shipped, and Germany is the major egg importer with 325,346 tonnes imported in 2021.

Table 1. Top Egg producers of the world in 2020. (Reference: FAO, 2022)

Countries	Egg production (thousand tonnes)	Global share %
China	30 248.1	34%
USA	6 607.7	8%
India	6 292	7%
Indonesia	5 044.4	6%
Brazil	3 260.9	4%
Mexico	3 016	3%
Japan	2 632.9	3%
Russia Federation	2 492.2	3%
Turkey	1 236.8	1%

The global population is projected to increase by 9 billion people by 2050 and there will be a tremendous rise in consumption of animal protein. As denoted overall global consumption of eggs has tripled during the past forty years, while consumer's demand for moral quality of products produced has increased. The consumption of eggs varies greatly among the different nations globally (Lei, 2021). In general, yearly consumption of eggs varies widely based on the national economy, from 300 g in African nations (like Ethiopia) to 23.1 kg/per capita in China. Egg consumption should be considered as a component of the answer to compensate the problems like malnutrition in numerous developing countries (OECD/FAO, 2023).

Table 2. Top Egg Consuming Countries in 2020-22. (Reference: OECD/FAO, 2023)

Countries	Per capita consumption (kg/capita)
Mexico	23.4
China	23.1
Japan	20.7
Russia	18.1
Malaysia	17.7
Argentina	17.7
Ukraine	17.2
Canada	16.3
Indonesia	16.2

POULTRY EGG FORMATION AND STRUCTURAL COMPOSITION

A normal poultry egg is made up of several structures from outside to inside including egg shell, shell membrane, air sac, albumen, vitelline membrane, chalazae, and egg yolk. The egg formation starts from the ovary (yolk formation) and ends in the vagina (oviposition). The main constituent parts of the egg yolk are synthesized in the liver which are then transferred through the blood circulation and will accumulate in the ovarian follicle. The large ovarian follicle delivers a fully developed egg yolk during ovulation (Nys and Guyot, 2011). Now the delivered egg yolk moves into the infundibulum (funnel-shaped) of the oviduct. The egg yolk remains in the infundibulum for 15 minutes to an hour, where the vitelline membrane is formed with the help of 137 proteins. The vitelline membrane is a thin layer surrounding the egg yolk helps to protect the yolk against infections. The egg yolk then passes into the magnum and stays for 3 – 4 hours where albumen production takes place (Kaspers, 2016). Albumen is a protein-rich substance that consists of water, protein, minerals, and free glucose. Unlike yolk proteins, albumen proteins (ovalbumin, ovomucin, avidin) are not produced by the liver but by the magnum's mucosal tubular glands and goblet cells. Albumen gets hydrated in the magnum, so it causes changes in viscosity forming a thinner liquid egg white (inside), a thicker viscous egg white (outside), and chalazae. Chalazae consist of protein fibers which is formed primarily in the infundibulum and magnum, it helps in maintaining the position of the yolk. In the Isthmus, both inner shell membrane (surrounding the albumen) and outer shell membrane (sticking with the shell) are formed by the network of protein fibers. Inner and outer shell membranes are tightly packed throughout the egg, yet they are separated at the blunt end of the egg which creates the air sac. From the isthmus, the egg moves downward into the uterus where the egg develops an ovoid shape due to an increase in volume of the shell membranes. Eventually, the outer egg membrane comes in contact with the uterine wall enabling the effective formation of eggshell. This process lasts up to 19 – 21 hours, which involves the production of an organic matrix comprising glycoproteins and mucopolysaccharides will get calcified ($CaCO_3$) to form the eggshell. The penultimate stage before oviposition is the formation of the cuticle (wax membrane) on

the eggshell. Cuticle consists of polysaccharides, lipids, proteins, and it serves as the primary defense against microbes (Kaspers, 2016).

Domestic poultry birds have different proportions of egg components depending on their species, genetic makeup, age, diet, management, and environment. The average weight of a white leghorn egg is 57g, with the weights of its components being 16g of yolk, 35g of albumen, and 6g of eggshell (Rath et al., 2015).

Table. 3 Structural Composition of eggs from various Domestic birds. (Reference: Nys and Guyot, 2011; Huang and Lin, 2011; Sun et al., 2019)

Species	Weight of the Egg (g)	Egg Albumin %	Egg Yolk %	Eggshell %
Chicken	50 - 70g	57 - 65%	25 - 33%	8.5 - 10.5%
Turkey	80 - 90g	54 - 58%	31 - 35%	8.5 - 10.5%
Quail	8 - 10g	52 - 62%	30 - 33%	7 - 9%
Guinea Fowl	35 - 45g	50 - 60%	25 - 35%	15%
Duck	60 - 90g	45 - 58%	28 - 35%	11 - 13%
Geese	130 - 150 g	49 - 55%	35 - 40%	9 - 11%

NUTRITIOUS COMPOSITION OF EGGS

A whole fresh egg consists of both macronutrients (lipids, protein, carbohydrates) and micronutrients (vitamins, and minerals). Fat-soluble vitamins (A, D, E) are found in egg yolk, whereas water-soluble vitamins (vitamin B) and trace minerals (P, Ca, K, Na) are found in both egg white and yolk. The major portion of the egg consists of water, protein, and fats, and it is devoid of fiber and Vitamin C (Ren et al., 2010; Réhault-Godbert et al., 2019). A standard boiled egg provides 78 calories of energy (Kuang et al., 2018).

Table 4. Fundamental composition of a Whole Egg. (Reference: Réhault-Godbert et al., 2019)

Proximate	Whole Egg	Egg Yolk	Egg Albumen
Water	76.1%	55.02%	87.72%
Protein	12.6%	15.5%	10.82%
Total Lipid	9.5%	26.71%	0.19%
Carbohydrates	0.7%	1.09%	0.85%
Ash	1.1%	1.68%	0.42%

Eggs serve as an excellent source of protein compared to other animal products, and they possess an average protein content of 12.58g per 100g of whole egg (Kuang et al., 2018). Egg albumen comprises

of 150 different proteins like ovalbumin (54%), ovomucoid (11%), ovomucin (3.5%), ovotransferrin (12%), and lysozyme (3.5%) among which the most prevalent is ovalbumin, accounting for fifty percent of total proteins present in egg white. Ovalbumin supplies various quantities of amino acids (alanine, arginine, isoleucine, serine) for human consumption (Abeyrathne et al., 2013b). Egg yolk contains various protein-embedded components like LDL (stores more than 95% of the free form of yolk cholesterol), HDL, livetins, and phosvitins, these components are divided between non-soluble protein clumps known as granules and a transparent yellow plasma. Apovitellenin-1, vitellogenin, apolipoprotein B, ovalbumin, ovomucin, and ovotransferrin are the most prevalent protein content of the yolk (Réhault-Godbert et al., 2019; Abeyrathne et al., 2022a). Along with protein, egg yolk also consists of a wide range of lipid compounds such as 60% triglycerides – saturated fatty acids (Palmitic, Arachidic, Stearic), and unsaturated fatty acids (Monounsaturated fatty acids – MUFAs, Polyunsaturated fatty acids – PUFAs), 33% phospholipids (phosphatidylcholine, sphingomyelin, Lys phosphatidylcholine), 5% cholesterol, 1% carotenoids (carotene, xanthophyll) (Kuang et al., 2018). Egg yolk and egg albumen are rich sources of vitamins A, D, E, K, B1, B2, B3, B5, B6, B9, and B12. Several studies signify that consuming two eggs per day will fulfill daily vitamin requirements. Hard-boiled egg is a major source of choline (680mg per 100g of egg yolk or 335mg per 100g of whole egg) compared to other animal-based sources (Réhault-Godbert et al., 2019; USDA).

Table 5. Nutritional Content of a Whole Chicken Egg (50.3g). (Reference: USDA)

Nutrient	Amount	Nutrient	Amount
Water	38.1 g	Vitamin B12	0.513 µg
Protein	6.24 g	Vitamin D_2 + D_3	49.5 IU
Total Lipid	5.01 g	Vitamin A	90.5 µg
Ash	0.428 g	Lipids	
Carbohydrate	0.483 g	Saturated Fatty Acid	1.61 g
Minerals		MUFAs	1.83 g
Calcium	24.1 mg	PUFAs	0.915 g
Phosphorus	92.6 mg	Zeaxanthin	115 µg
Magnesium	5.73 mg	Lutein	116 µg
Potassium	66.4 mg	Cholesterol	207 mg
Sodium	64.9 mg	Essential Amino Acids	
Iron	0.84 mg	Isoleucine	0.31 g
Selenium	15.6 µg	Methionine	0.21 g
Vitamins		Valine	0.369 g
Thiamin	0.039 mg	Lysine	0.418 g
Riboflavin	0.211 mg	Histidine	0.142 g
Niacin	0.2 mg	Leucine	0.528 g
Folate	35.7 mg	Tryptophan	0.083 g
Choline	169 mg	Phenylalanine	0.332 g

HEALTH BENEFITS OF CONSUMING EGGS IN OUR DAILY DIET

Dietary plant-based proteins result in reduced muscle protein synthesis because they are less digestible (45% - 80%), contain less leucine, and lack essential amino acids compared to egg, meat, and dairy products (Puglisi and Fernandez, 2022). The World Health Organization (WHO) states that eggs have the highest digestibility quality (97%) and protein digestibility-corrected amino acid score (PDCAAS) than any other products, making eggs among the best sources of protein. Leucine is an essential amino acid which is most important since it is the chief booster of muscle protein synthesis. For effective stimulation of muscle protein synthesis, 700 to 3000 mg of leucine should be consumed daily. A single egg has around 528 mg of leucine, which makes it as a great choice for reaching this leucine need to improve the body's muscular growth and strength (Puglisi and Fernandez, 2022). Several studies denote feeding only the egg white and limiting the yolk part will reduce the protein intake value of the whole egg. The advantages of eating entire eggs rather than simply egg whites are supported to improve plasma lipoproteins levels, muscle protein synthesis, and lower the risk of various cardiovascular diseases like atherosclerosis. Egg yolk also has several high-quality proteins (Puglisi and Fernandez, 2022). Egg white proteins like lysozyme, ovomucin, and ovotransferrin-derived peptides, exhibit anti-cancerous and tumor-inhibitory properties with the help of cytotoxic action and immune system activation (Réhault-Godbert et al., 2019).

Egg yolk phospholipids like sphingomyelin, phosphatidylcholine, and egg white protein like ovomucin have the properties to lower the cholesterol absorption in the small intestine. Sulfur-containing amino acids - cysteine supports the maintenance of lipid metabolism by reducing the serum cholesterol level (Kuang et al., 2018; Abeyrathne et al., 2022a). Egg whites and vitelline membrane consists of antimicrobial components like ovotransferrin, ovomucin, phosvitin, pleiotrophin, and cystatin which has antiviral, antibacterial, and antifungal properties. Antibacterial action is based on various bactericidal or bacteriostatic activities. Some antimicrobial proteins like lysozyme and avian beta-defensin 11 binds to the bacterial cell walls and cause death of the microbial pathogens (Réhault-Godbert et al., 2019). Vitamin E, minerals (zinc, selenium), carotenoids, phospholipids (Phosphatidylethanolamine), egg white proteins (ovotransferrin, ovomucoid hydrolysates), and phosvitin are some of the important antioxidant components found in eggs. Antioxidant components decrease inflammatory cytokine production, and oxidative stress by reducing free radical formation (Réhault-Godbert et al., 2019). In humans, inadequate choline in the diet can result in neural fetal malformations, fatty liver, and neurological dysfunctions. The growth of cholinergic neurons and the retention and release of acetylcholine in the forebrain are all dependent on choline. Hence, both pregnant and nursing women should take between 450 to 550 mg of choline per day. As eggs are a rich source of choline consuming eggs daily will take off the requirement of choline. Choline intake enhances eyesight, lowers the risk of cardiovascular disease, and overall human health. It also possesses immunomodulatory effects, which reduce inflammatory indicators and fatigue (Abeyrathne et al., 2022a).

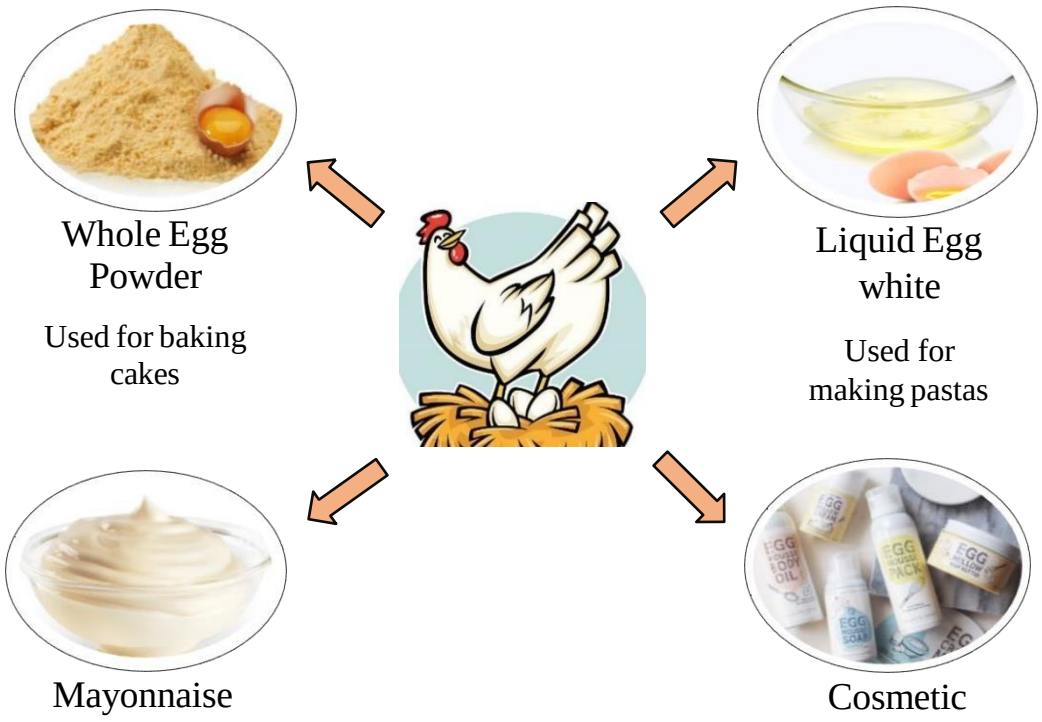

Figure 1: Commercially Available Poultry Egg Products

NUTRIENT ENRICHED EGGS

The nutritional content of eggs can be altered in order to enhance the levels of omega-3 fatty acids, vitamins E, selenium, and carotenoids. These nutrient-rich eggs can benefit people to meet their dietary need and helps to prevent other health conditions like rheumatoid arthritis, thrombosis, and atherosclerosis. Consumption of vitamin E, carotenoid, and Selenium-enriched eggs enhances the antioxidative state during normal body metabolism (Hayat et al., 2014). These nutrient-rich eggs are produced by manipulating the dietary ration of the birds so that we can get the increased proportion of desired substances in the table egg. Omega-3 fatty acid enriched eggs are a common type of enhancing nutrition content of normal eggs. It is achieved by adding various kinds of oils rich in omega-3 fatty acids included in the diet. Omega-3 fatty acids can be derived via fish oil, and marine algae, which are rich sources of PUFA, and DHA. The main health advantages of using enhanced eggs are due to the poor ability to convert linolenic acid to DHA, especially among older people and young infants. Carotenoids that exist in marine algae can increase the oxidative resilience in omega-3 fatty acid-enriched eggs (Ren et al., 2013). Vitamin E is vital for lowering the danger of oxidative stress and ageing. A greater quantity of vitamin E in ration, particularly included with the flaxseed oil can increase egg yolk taste and overall level of vitamin E in egg. Vitamin E enriched eggs have greater antioxidant capacity, lower the incidence of cancer, and lessen the risk of coronary artery diseases (Martino et al., 2014). Selenium enriched eggs can increase sperm quality in infertile men. Adding to it selenium may also lower the risk of osteoarthritis, eye conditions, gastrointestinal distress, immunodeficient status, anemia, and muscle weakness. Selenium can increase vascular circulation by physiologically modulating the lipoproteins giving extra protection against the onset of cardio-vascular disease (Singh et al., 2012). Plant-sourced diet comprises of biologically active metabolites known as phytobiotics. They are commonly utilized in the

poultry diet to enhance productivity and to produce herbal-enriched eggs. Herbs such as garlic, cabbage, alfalfa, grape pulp, turmeric powder, yeast, fermented byproducts, and various legumes are added. Herbal enriched eggs consist of active ingredients such as phytosterols, nirangenin, quercitin, allylic sulfide, carotenoid pigments, taurine, and eugenic acid. In comparison with regular eggs, these eggs contain lower levels of LDL. Several studies suggest that consumption of herbal-enriched eggs showed significant effects on the human body, which include declines in triglyceride levels, with increased HDL cholesterol levels, and enhanced immune systems. These eggs also has various properties like immunomodulatory, anti-inflammatory, and antioxidant characteristics (Muduli et al., 2018).

CONCLUSION

Consumption of eggs is undeniably necessary and has a lot of positive attributes that safeguard and maintain human health throughout their lifetime. In underdeveloped and developing countries, eggs and other high-protein products are not included in diets from a young age causing problems related to nutritional deficiency disorders. Malnutrition can be avoided by including eggs in the diet of children who are at risk. It is essential to educate families with limited resources about the affordability of eggs, their potential to provide necessary nutrients and their health benefits for growing children and infants. The expansion of the poultry sector worldwide provides enormous benefits to the diet, well-being, and socioeconomic development of poor people.

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