Advances in **Veterinary Research** for Sustainable Development of Livestock Sector

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Chapter 12
Nutritional Strategies for Production of Designer (Nutrient Enriched) Eggs

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Introduction

Changes in lifestyle, improper nutrition and reduced physical activity have led to epidemic of non-infectious diseases, leading to health issues and even death. Therefore, there is increasing interest among the population to eat functional foods which have health benefits. "A designer/functional food is a food and is consumed as part of diet and is demonstrated to have physiological benefits and/or reduce the risk of chronic diseases, or minimize the risk of other health concerns" (ILFS, 1999). Some of the designer foods in the market are designer eggs, designer meat, designer milk, designer oil, designer vegetables, designer grains etc.

The poultry eggs are nutrient dense food. Eggs regarded as convenient, low-calorie source of high-quality protein with several other essential and micronutrients. Egg contains most of the essential nutrients including vitamins, minerals and other bioactive compounds. Eggs contain highly digestible protein that contain the important amino acids in a profile that is similar to ideal human requirements. An egg can deliver 10% protein, 6% vitamin A, 6% vitamin D, 3% vitamin E, 15% vitamin B2, 4% vitamin B6, 8% vitamin B12, 6% folic acid, 2% thiamine, 4-10% zinc and 4-10% iron of the recommended daily allowance for human beings (Song and Kerver, 2000). The nutrients in eggs can be improved greatly through the dietary manipulation. Eggs enriched with critical trace minerals, vitamins, omega -3 fatty acids, immunoglobulins, carotenoids and antioxidants can be an excellent source of nutrients in human diet. Likewise, saturated fat, cholesterol and n-6 fatty acids can be decreased by dietary interventions.

Several attempts were made to modify the eggs by adding ingredients which are beneficial for the health or by eliminating or reducing components that are harmful. This modification resulted in development of functional or designer eggs. Diets of birds' influence qualities of eggs in terms of nutritive value, acceptability, human health and processing. Eggs can be designed through dietary approaches either through supplementation of specific nutrients, or certain herbs or specific drugs that have functional and therapeutic properties.

Designer Eggs

Designer eggs are those specially produced or modified eggs which are rich in additional nutrients and health promoting components like omega 3 fatty acids, selenium, vitamin E, carotenoids, chelated minerals and other immune-modulating factors (Surai and Sparks, 2001). Designer eggs could modulate the body immune functions, treat some diseases and health problems like cancer and diabetes, regulate blood pressure, decrease cholesterol levels and alleviate cardiac problems and allergies. That's why designer eggs are sold at a premium price and have a better consumer preference than the regular eggs. Commercially it

is possible to produce designer eggs enriched with different nutrients simultaneously or with a single nutrient.

Production of designer eggs

There are different ways by which designer eggs can be produced. Egg composition can be modified by genetic approach by selecting for genes that may alter metabolism resulting in synthesis of compounds that are deposited in egg or reduced synthesis of undesirable compounds like cholesterol. Another method is changing membrane transport which may increase the deposition of critical nutrients in the egg. However, these methods are not acceptable for many people because of unintended consequences due to genetic manipulation or hormone supplementation. Altering diet fed to hen is the most acceptable method for production of designer eggs.

For enriching egg through dietary modifications, identification and selection of the specific nutrient, which has high nutrient transfer efficiency from feed to egg is important. The nutrient also should not be toxic and should not interfere with other nutrients affecting bird's health. Ultimately the nutrient should supply more than 10% of recommended daily allowance of the nutrient. The designer egg produced should be stable at cooking and should not change keeping quality, taste and smell of egg.

Omega-3 fatty acids enriched eggs

Omega 3 fatty acids are poly unsaturated fatty acids which have the first C-C double bond at the third carbon position from omega end of carbon chain. The health benefits of omega-3 polyunsaturated fatty acids (n−3 PUFA) are well known (Simopoulos, 2000). The major omega 3 fatty acids include alpha-linolenic acid (ALA), decosahexanoic acid (DHA) and eicosapentanoic acid (EPA). The ALA is metabolized in the body to DHA and EPA. The DHA produce benefits more than other omega 3 fatty acids. The conversion of ALA to DHA is not efficient in young children and elderly. In most of the countries, the recommended daily intake of Omega 3 fatty acids is rarely fulfilled. Therefore, enrichment of commonly occurring foods can boost intake of these fatty acids. It has been reported by different research workers that the total fat concentration in the egg yolk cannot be reduced. It is well known that the fatty acid composition of egg can be changed, by changing the hens' diet. Flax seed (linseed), marine algae, fish oil and rape seed oil are added to chicken feed to increase the omega - 3 fatty acid content in the egg yolk, at the expense of saturated fatty acids like palmitic and stearic acids. In designer eggs the N-6 / N-3 PUFA ratio can be decreased, from 15-20 in regular eggs. Designer eggs can be produced which can supply 50% of the daily requirement of N-3 PUFA to the consumers. When these eggs are consumed at two eggs per day for two months, serum HDL cholesterol content elevated and serum triglycerides decreased in human volunteers.

Though feeding of flaxseeds /linseeds or flax seed oil increased the LNA content, however very less increase in DHA or EPA was observed. Since conversion of LNA to DPA is very poor in young children and elderly, this may not provide much health benefits to them. However, feeding fish oil from tuna, herring or menhaden or marine algae significantly enhanced the level of DHA in egg. Diets containing 3% to 4% fish oil can produce eggs containing 180 to 250mg DHA/egg (van Elswyk,1997). Efficiency of transfer of omega 3 fatty acids also varies

with source, dietary dose levels and dietary composition. In general transfer efficiency is very low in linseed oil as compared to marine algae or fish oil.

Since the N-3 PUFA will undergo rancidity quickly leading to fishy taint or off flavors. It is essential to prevent the rancidity of the designer egg yolk lipids, by incorporating anti-oxidants in the hens' diet. Fishy taint or off flavor can be reduced by adding vitamin E or synthetic antioxidants in the diet and by reducing the level of oil supplementation or by feeding encapsulated oil. There are also reports that suggest that high level of flax seed oil in the diet may interfere with minerals and enzymes which may affect general digestibility and bioavailability of nutrients. Cooking characteristics of eggs are in general not affected due to enrichment. Many companies in India and abroad are marketing omega 3 enriched eggs.

Low cholesterol eggs

Though several workers observed that there is no correlation between dietary cholesterol and the serum cholesterol levels, general public are scared of eating high cholesterol foods, like eggs. An egg contains 180 to 220mg of cholesterol. Reducing cholesterol content of egg is difficult to achieve because cholesterol is essential for the nutritional and structural requirements for avian embryonic development (Kuksis, 1992). Research for lowering cholesterol focused mainly on dietary or pharmacological intervention. N-3 PUFA, Chromium, nicotinic acid, copper, basil (tulsi), garlic, statins, plant sterols, supplementation to chicken feed may reduce the yolk cholesterol levels significantly. Similarly, dietary linseed oil, garlic, basil, spirulina, bay leaves, nicotinic acid, guar gum, grape seed pulp, tomato pomace, citrus pulp, chelated copper, organic chromium, roselle seeds and many more herbs in chicken diets may reduce the yolk and chicken fat cholesterol levels by 10-25%. Dehydrated alfa-alfa reduces cholesterol content and total lipids in chicken breast meat. Different vegetable oils like soyabean oil, sunflower oil, linseed oil, canola oil modify fat and may reduce cholesterol content in meat. Combination of these substances may be more effective than single substance in reducing the cholesterol levels. The use of drugs like statins also result in reducing cholesterol content upto 50% but their acceptability is very low, because of concern of consumers regarding the excretion of residues/metabolites in eggs. Genetic selection studies for lowering egg cholesterol content have not been successful.

Vitamin enriched eggs

Vitamin composition of egg can be modified by dietary vitamin supplementation (Leeson and Caston, 2003). Several studies have confirmed that it is possible to produce novel eggs with higher levels of vitamins Vitamin A, D, K, E and water soluble vitamins such as vitamin B_{12} and folic acid. Fat soluble vitamins are stored in egg yolk. Increasing supplementation fat soluble vitamins like vitamin A, D, and E resulted in linear increase in egg vitamin contents. Increasing the retinyl acetate concentration from 4000 to 16000 IU/kg produced vitamin A enriched egg, yolk retinol content increased from 10.3 to 24.0 IU/g yolk (Squires and Naber, 1993). Yolk retinol content can be increased up to 20 folds by feeding very high level of retinyl acetate in the diet (Surai *et al.,* 1998). Mattila *et al*. (1999) reported that when cholecalciferol content of feed increased from 2496 to 8649 IU/kg feed, the cholecalciferol content of egg yolk raised 6 fold (3.4 to 21 µg/100 g yolk). It is reported that 8-13 days of high vitamin supplementation is

required to enrich the egg with the vitamin (Mattila *et al.,* 2003). Naber (1993) classified the transfer efficiency of different vitamins from hens' diet to the egg and grouped the vitamins into low, medium, high and very high transfer efficiencies. The transfer efficiencies of different vitamins from feed to egg are given in Table 1. Vitamins with higher transfer efficiencies can be incorporated in chicken diet to produce vitamins enriched diet. Vitamin A, D, E and K enriched eggs are already available in market.

Table 1. Transfer efficiencies of vitamins (Naber, 1993).

Transfer efficiency	Vitamin
Low (5 to 10%)	Vitamin K1, Thiamine
Medium (15 to 25%)	Folacin, Vit D3
High (40 to 50%)	Vitamin E, Riboflavin, pantothenic acid, Biotin, B12
Very High (60 to 80%)	Vitamin A

Minerals enriched eggs

The trace minerals content of eggs can also be increased by manipulating the diet of laying hens. Several studies have confirmed that it is possible to produce novel eggs with higher levels of minerals such as iodine, iron, zinc and selenium. Eggs are served regularly in the noon meal schemes implemented by many state governments in our country. Since tables eggs cannot be adulterated easily and could be a better vehicle for the delivery of micronutrients with high bioavailability, bio-fortified eggs can be produced in large quantities and supplied for public consumption. However, feeding of excess minerals (inorganic) in the diet of hens could increase the cost of egg production and sometimes results in mineral – mineral / mineral – vitamin interactions in the diet which necessitates validation studies scientifically.

Production of table eggs fortified with micronutrients such as iron, copper, zinc, iodine and chromium to tackle the community nutritional problems such as anemia, stunting, iodine deficiency disorders etc. is highly essential. It is possible to supply 50% of the RDA for selenium in one egg by supplementing the feed of the layer hen with 0.4ppm in the form of organic selenium (Surai, 2000). Then iron content of egg yolk can be increased upto 40% with supplementation of organic or inorganic iron (Paik *et al.,* 2009). Similarly, iodine (Kroupova *et al.,* 1999), zinc (Bahakaim *et al.,* 2004) and chromium content (Kang *et al.,* 1996) can be increased by supplementation of organic or inorganic minerals. When minerals are added in higher amounts, there is possibility of toxicity or interference with absorption of other minerals and vitamins leading to their deficiency.

Carotenoid enriched eggs

In many countries, deep yellow or orange colour yolks and yellow skin broilers are preferred over pale yolks and skin (Leeson and Caston, 2004; Kang *et al.,* 2003). The yolk color is a reflection of its pigment content and most of the carotenoids in egg yolk are xanthophylls. The most common carotenoids found in egg yolk are lutein and xanthophylls (Sahoo and Jena, 2014). Corn gluten meal, alfalfa, spirulina, capsicum and marigold petal meal contain carotenoids

which on supplementation may produce orange or yellow colour yolk (Sahoo and Jena, 2014). Besides providing attractive colour, they act as anti-oxidants and anti-carcinogenic agents. Some of the pigments are having vitamin A activity. The lutein has specific role in safeguarding of retina. Most of these natural pigment sources are used in feeds at 1-3 % levels to increase the yolk and skin colour. The active pigments extracted from these sources are sufficient at 0.05 - 0.1 % level, to give the same level of pigmentation. In elderly people macular degeneration is one of major cause of blindness and egg carotenoids are shown to reduce the incidence. In developed countries, carotenoid (lutein and zeaxanthin) enriched eggs are marketed for elderly population to improve healthcare of eyes.

Designer eggs for improving immunity

Lysozyme (G1-globulin), G2 and G3 globulins, ovomacroglobulin etc are naturally occurring compounds in egg. The globulin antibodies can be used in the cure of immune-compromised patients. These eggs are reported to possess immune-stimulant and anti-viral properties. The Egg IgY level can be increased by nutritional approach. Supplementation with herbs like garlic, rosemary, fenugreek, turmeric, ashwagandha, spirulina, etc., may be helpful for eliciting immune response in humans.

Conclusions

By manipulating the diet of chicken with these feed supplements, value added and health promoting chicken egg, meat and their products can be made available to the consumers. Designer eggs containing higher levels of critical nutrients like fatty acids, vitamins, minerals, antioxidants can be produced and supplied to the vulnerable population especially in developing countries like India where micro nutrient deficiency is more common. Designer eggs containing DHA, lower cholesterol, selenium, vitamin E, natural carotenoids and Pro-Vitamin A enriched eggs are available in the commercial market. However, table eggs fortified with both multi-minerals and vitamins capable of tackling the problems of anemia and stunting are not available in the market. It is also utmost important to consider safety and quality of modified eggs. The product should be of consistent quality so that consumers are sure of getting the enhanced nutrients.

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