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Dietary Manipulations for Improvement of Egg Quality for Human Consumption

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Egg:

Oval reproductive body produced by female of poultry in which nutritious semi-liquid content are packed in hard calcareous shell.

Composition of egg (per 100g):

Moisture, g	76.15
Protein, g	12.56
Total lipids, g	9.51
Carbohydrate, g	0.72
Cholesterol, mg	372
Calcium, mg	56
Calorie, Kcal	143

USDA National Nutrient Database for Standard Reference, Release 23 (2010)

Since the 1990s, food has evolved into an exciting area of the food and nutrition sciences known as functional foods which can provide health benefits beyond basic nutrition. Functional food can be defined as those providing health benefits beyond basic nutrition and include whole fortified, enriched or enhanced foods which have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis at effective levels. Traditionally, eggs have not been regarded as a functional food because of their perceived link with adverse effects on blood cholesterol. However, research over the last 3 decades has shown that dietary cholesterol only has a small effect on plasma cholesterol levels and has little relationship to heart disease incidence. The egg is a nutrient dense food and is now regarded as an excellent, inexpensive, convenient and low calorie source of high quality protein and several important nutrients such as riboflavin, selenium, choline and vitamin B12.

Consumer demand for food products of superior health quality has generated interest in modifying the lipid composition and enriching poultry meat and eggs with beneficial nutrients. Meeting consumer

demands is a constant challenge for the animal food industry. Many consumers desire somewhat distinct products with respect to safety, healthfulness, freshness, taste, color, etc. To tap into this market, companies have developed several designer and speciality eggs which have appeared on store shelves.

Modified or enriched eggs or super eggs are those in which the content has been modified from the standard eggs. These eggs may be classified as nutritionally enhanced eggs, value added eggs, processed eggs. The most commonly available modified eggs are vegetarian eggs and eggs with modified fat content, vegetarian eggs may be produced from hens fed on grain diet, free of animal fat and by-product. However, modified fat content of the eggs are marketed as a reduced amount of cholesterol, less saturated fat, elevated amount of omega-a fatty acid, higher vitamin content and high amount of iodine. However, the organic and free range eggs are marketed as value added eggs. The nutritional content of the organic eggs will be equal to the generic eggs if the feed is of similar quality

Strategies to consider in egg nutrient enrichment

When considering egg enrichment with nutrients, several factors need to be taken into account:

(a) Efficiency of nutrient transfer from feed to the egg

(b) Availability of commercial sources of effective feed forms of the nutrient

(c) Possible toxic effects of nutrients for the laying hens (Vitamin A and D are toxic for chickens at high levels)

(d) Amount of nutrient delivered with an egg in comparison with Recommended Dietary Allowance (RDA)

e) Established health promoting properties of nutrients and their shortage in a modern diet. (Justification for vitamin E inclusion is that it is an important component of antioxidant defences, diets are deficient in this nutrient and consumption of high doses is beneficial)

(f) Possible interactions with assimilation of other nutrients from the egg

(g) Stability during cooking

(h) Effect of nutrient enrichment on appearance and taste (Vitamin E, carotenoids and selenium do not affect egg taste but help prevent fishy taste in ω-3 eggs)

(i) Possibilities to claim health benefits

Omega -3 (ω-3) Fatty Acids enrichment

Recently, eggs have gained attention as an alternative to fish and oilseeds as a source of Omega -3 fatty acids. Generally people tend to avoid egg yolk but yolk only contains omega 3 fatty acids. The total fat content in the egg yolk cannot be altered; but its fatty acid composition can be altered, by changing the type of oil used in the hen's diet. Omega-3 is an essential fatty acid with a treasure trove of health benefits. Found naturally in marine micro algae (*Crypthecodinium cohnii*), fishes which consumes these microalgae and some plants. Omega-3 is a building block for foetal vision development and brain function. In adults, omega-3 lowers risk of heart disease and cancer of the breast, colon and prostate. Its anti-inflammatory properties help decrease episodes of asthma and pain associated with rheumatoid arthritis. One normal eggs contain only 50- 100mg of omega 3 fatty acids and which can be increased to 500mg or more with dietary modifications in the hen's 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. This n-3 PUFA in egg yolk has decreased the serum triglycerides and increased the serum HDL-Cholesterol levels and also found to decrease incidence of atherosclerosis and hypertension. Studies shows that by using designer eggs the N-6 / N-3 PUFA ratio are decreased to about 1.5, from as much as 20 in regular eggs. This favourable change in designer eggs, will supply about 50% of the daily requirement of N-3 PUFA to the consumers, without any change in the sensory quality of the egg. In short for all especially those who don't eat fish will probably find the most value in Omega-3-enriched eggs.

Diseases associated with inadequate ω-3 consumption

The diseases associated with inadequate dietary ω-3 PUFA are as follows. The imbalance of dietary ω-6: ω-3 can cause:

• Atherosclerosis (hardening and narrowing of arteries due to deposits in arterial walls)

• Thrombosis (blood clot within heart/blood vessels impeding blood flow)

• Arrhythmia (irregular heartbeats)

• Hypertension (elevated blood pressure)

• Rheumatoid arthritis (degenerative disease of joints)

• Visual acuity reduced (impaired vision)

• Brain development affected (learning difficulties)

• Cancer (breast, colon, pancreas, prostate)

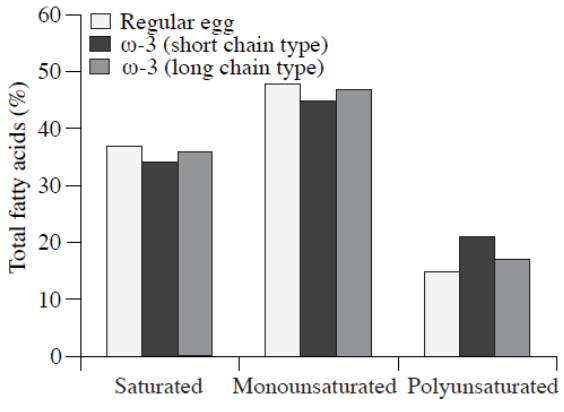
• Atopic dermatitis, lupus, psoriasis, migraine, multiple sclerosis

• Bronchial asthma, diabetes mellitus and ulcerative colitis

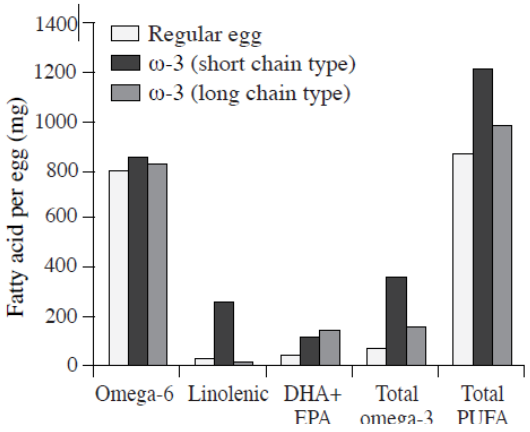
Modification of fatty acid profile of eggs

The fatty acid composition of hen egg yolk can be modified through alterations in the diet. Feeding with sources rich in long-chain (LC) or short chain (SC) ω-3-fatty acids increases the content of these fatty acids in egg yolk. Omega-3 enriched eggs can either contain higher levels of the marine type ω-3 PUFA, DHA and EPA which are more commonly found in deep sea cold water fish (such as salmon, mackerel, herring, tuna, bluefish and anchovies), fish oil and marine algae *Schizochytrium* sp. Or the terrestrial type ω-3 PUFA, alpha linolenic acid (LNA) found in canola oil, soybean oil, and flaxseed, walnut, spinach and mustard greens. The total fat content of the ω-3 eggs and the cholesterol level may be less or quite similar to regular eggs. However, supplementation with fishmeal or fish oil can exert a negative influence on the sensory properties of the egg (Nash et al. 1996). Supplementation with ω-3 from plant sources results in much lower concentrations of LC ω-3 in the egg as this is due to oxidation of the LNA and low conversion of LNA to DHA.

The two major types of ω-3 eggs sold are either the SC ω-3 type eggs predominantly with the terrestrial alpha linoenic acid (LNA) and the LC ω-3 type eggs predominantly with the marine DHA and EPA. For the production over an 8-week period for ω-3 eggs, feed conversion ratio and ME intake required to produce per kg egg by the ω-3 egg production system is as efficient as the conventional egg production system. The SC and LC ω-3 type eggs contain 5 and 3 times more ω-3 respectively than the regular egg which has a total of 65 mg ω-3 fatty acids per egg. The ratio of ω-6: ω-3 is 12.1:1, 2.3:1 and 5.1:1 respectively for the regular, SC and LC type ω-3



A. Fatty acid content (%) of total fatty acids in regular and omega-3 eggs



B. Polyunsaturated fatty acids content in regular and omega-3 eggs

Herbal enriched super eggs

Phytobiotics or plant-derived products containing several plant secondary metabolites can be used in poultry feed to improve the performance of hen and to produce herbal enriched super eggs. Chicken feed will be supplemented with herbs like garlic/onion leaves, spirulina, basil leaves, turmeric powder, citrus pulp, flaxseed, red pepper, fenugreek seeds etc. These super eggs will be having a lower LDL cholesterol, immunomodulator property, antioxidant, anticarcinogenic properties, higher omega-3 fatty acids etc. For example normal egg have vitamin E content of 90-100 µg /g yolk whereas herbal supplemented egg have 220 – 240 µg / g yolk which added to its increased antioxidant property. All these indicating that the overall health promotion in hens as well as possible health promotion in humans is possible by popularizing herbal enriched eggs

Source	**Active principle**	**Effect on human health**
Garlic, onion and their leaves	Allicin, Allylic sulfide	Lower L.D.L. cholesterol and anticarcinogenic
Sugar beet, grape pulp	Betaine	Reduces plasma homocysteine, which damages arterial walls
Spirulina, marigold petals, alfalfa, red pepper	Carotenoid pigments	Antioxidant, anticarcinogenic
Basil leaves	Eugenol, eugenic acid	Immunomodulators
Turmeric powder	Flavonoid compounds	Antimicrobial, antioxidant
Bay (curry) leaves, Marigold petals	Lutein	Antioxidants, Improves vision
Tomato pomace, grape pulp	Lycopene	Lowers LDL (bad) cholesterol, antioxidant, anticarcinogenic
Citrus pulp	Nirangenin	Reduces LDL cholesterol
Flax seed, canola, fish, oils insects, worms	O-3 PUFA	Reduces LDL cholesterol, hypertension, angina, atherosclerosis
Seeds, weeds, legumes fenugreek	Phytosterols	Increases HDL (good) cholesterol, reduces blood sugar
Fenugreek, spices	Quercitin,Luteolin, Diosgenin, citogenin	Stimulates insulin secretion, antimicrobial, tonic
Brewery waste, yeast, fermented products	Statin	Lowers LDL cholesterol
Brocoli, cauliflower, cabbage, radish leaves, waste	Sulphoraphane	Anticarcinogenic and antioxidant

Lowering Cholesterol Content

Even though the dietary cholesterol is insignificantly correlated with the serum cholesterol levels, the consumers are scared of high cholesterol foods, like eggs. A large egg contains about 200 mg of cholesterol and chicken meat contains about 60 mg per 100 g. At present low cholesterol eggs can be achieved either by reducing the amount of cholesterol per egg, by reducing the size of the yolk or by altering the lipid profile of the yolk. Research towards lowering egg cholesterol has centered mostly on dietary and pharmacological interventions. Chromium, copper, nicotinic acid, statins, garlic, basil (tulasi), plant sterols, N-3 PUFA supplementation to chicken feed will reduce the yolk cholesterol levels significantly.

Similarly, dietary Linseed oil =2-4%, Fish oil (body oil and not liver oil)=1-2%, Garlic=0.5%, Basil=0.3%, Spirulina=0.2%, Bay leaves=0.5%, Nicotinic acid=200mg / kg, Neomycin=10ppm, Statins of yeast=0.5-1%, Guar Gum=1%, Grape seed pulp / Tomato pomace (lycopene)=2-5%, Citrus pulp (nirangenin)=2-5%, Chelated Copper=200ppm, Organic Chromium=2ppm, Roselle seeds=0.5% and many more herbs in chicken diets will reduce the yolk and body cholesterol levels by 10-25%. Moreover, these substances are having synergistic effect in reducing the cholesterol levels. Hence a combination of these supplements will be more beneficial, rather than a single substance. One of the best advantages of the low cholesterol egg is in cholostrophobia among the consumers. By reducing the cholesterol level in plasma we can reduce the chances of coronary heart disease and heart attack.

Anti Oxidants in eggs

Egg is a rich source of natural antioxidants like vitamin-E, selenium, carotenoid pigments, flavinoid compounds, lecithin and phosvitin. These compounds will protect the fat-soluble vitamins and other yolk lipids from oxidative rancidity. However, these levels are not sufficient to protect the designer eggs rich in N-3 PUFA. Hence it is essential to increase the anti-oxidant levels in the designer eggs. The designer egg not only contain high levels of the above anti-oxidants; but also contain synthetic anti-oxidants like Ethoxyquin and anti-oxidants of herbal origin such as Lycopene, Curcumin, Sulforaphene, Carnosine, Quercetin, depending upon the herbs used in hens diet. Supplementation of these anti-oxidants in hen’s diet will increase their levels in the egg.

The advantages of enrichment of the egg with anti oxidants include:

- Decreased susceptibility to lipid peroxidation
- Prevention of fishy odour to the product
- Designer foods could be a good source of antioxidants in human diet

- Prevents destruction of fat-soluble vitamins
- Prevents denaturation of natural fat-soluble pigments
- Promotes the overall health of the consumers

For designer egg production, vitamin E and organic selenium can be added as anti-oxidants at levels of 200-400mg/kg and 0.1-0.3ppm, respectively. Besides these, other anti-oxidants as chemicals and herbs may be added, to prevent oxidative rancidity.

Vitamin-E enriched designer *eggs:*

Vitamin E enriched eggs can be produced with a higher amount of vitamin-E as compared to normal eggs by feeding hens on diet high in vitamin-E. The higher contents of vitamin-E can be obtained by supplementation of poultry feed in the form of natural sources found in butter, milk, vegetable and nut oils. The extra addition of vitamin-E in the diet of hens leads to the following advantages:

- Vitamin E reduces free radicals in blood
- Decreases risk of cancer and ageing process due to the reduction in the formation of the free radicals formation
- May reduce the risk of heart disease since it is an antioxidant
- Vitamin E acts as an antioxidant that results in delay of the development off odours

Immunomodulating Egg Production:

The eggs naturally contain certain specific compound like lysozyme (G1-globulin), G2 and G3 globulin, ovomacro globulin, antibodies etc. The globulin antibodies are natural antimicrobials and immunostimulants in the egg that can be utilized in the cure of immunosuppressed patients like AIDS patient. Chicken egg is abundant in antibodies like "IgY"; which is cheaper and better than mammalian immunoglobulin "IgG". In a 6-week period, a hen produces about 298mg of specific antibodies, compared with only 17mg from a rabbit. This "IgY" can be used to treat human rotavirus, E.coli, Streptococcus, Pseudomonas, Staphylococcus and Salmonella infections.

The IgY level in the egg can be increased by dietary manipulations. The functional feed rich in omega - 3 fatty acids and anti-oxidants itself will increase the IgY level in the egg. Herbal supplementation will further boost the IgY level in the egg. Among the herbs, Basil leaves (Tulasi) at 0.3-0.5 % dietary level is having the highest ability to boost the IgY level in the egg. Other herbs like Rosemary, Turmeric, Garlic, Fenugreek, Spirulina, Aswagantha, Arogyapacha etc., are also possessing immunomodulating properties.

Pigment Enrichment of Yolk and Skin

The color of the yolk is a reflection of its pigment content. In addition, the type of pigment in the egg and its concentration are directly influenced by the dietary concentration of any particular pigment. In many countries, deep yellow or orange colour yolks are preferred over pale yolks. Natural carotenoid pigments like carotenes, xanthophylls, cryptoxanthin, zeaxanthin, lutein present in alfalfa, corn gluten meal, blue green algae - spirulina, marigold petal meal and capsicum will impart rich yellow and orange colours to the yolk. Some of the pigments are having vitamin A activity.

Most of these natural pigment sources are used in feeds at 1-5 % levels to increase the yolk colour. The active pigments extracted from these sources are sufficient at 0.05 - 0.1 % level, to give the same level of pigmentation. Turmeric powder at 0.5 kg along with red chilli powder at 1 kg / tonne of feed, not only improve the yolk colour, but also act as anti-microbial agents and anti-oxidants. Fat soluble Azo dyes are also used for pigmentation, but this is banned in many countries. The beneficial effects of pigment enrichment in the yolk include:

- It assists in preventing muscular degeneration
- It is responsible for attractive colour of yolk
- It acts as antioxidant and anti carcinogenic agent
- Lutein is responsible for safeguard to the retina

Pharmaceutical designer eggs:

Now a day, researchers are producing genetically modified chickens through the genetic manipulation which are capable to produce certain pharmaceutical compounds and those compounds can be harvested through eggs like insulin which are used for treatment of diabetes. The hen, like all animals, produces antibodies to neutralize the antigens (viruses, bacteria, etc.) to which she is exposed to each day. These antibodies circulate throughout her body and are transferred to her egg as protection to the developing chick. Immunologists are taking advantage of the fact that the hen can develop antibodies against a large array of antigens and concentrate them in the egg. Specific antigens are now being selected and injected into the hen that develops antibodies against them. As new biotechnology knowledge is gained in this area, designer eggs in the future may be produced that result in a range of antibodies for treatment against snake venoms to the countering of microorganisms which cause tooth decay.

Mineral enriched designer eggs:

Many types of minerals can also be enriched in the production minerals enriched designer eggs. Among these selenium and iodine are one of them followed by chromium and copper. This can be achieved by the dietary manipulation of hen's diet. These trace minerals are very important for human health because the deficiency of these trace minerals leading to development of certain deficiency disease. Normally a hen egg contain almost about 53 µg iodine/100g of their edible portion, that is the *33%* of the approximate dietary intake but after supplementation potassium iodide i.e., KI at the @ of 5 mg of their feed level of KI does not affect the performance of the hen. It increases the iodine content from 26-88 µg in 60 g hen egg tremendously.

Selenium enriched designer eggs:

Now a days, selenium enriched eggs are available in more 25 countries in the world. Among these Russia is the most advanced country for the production of selenium enriched eggs. The prices of the selenium enriched eggs are higher than normal table eggs. Today the selenium content of eggs can be easily modified by the supplementation of organic selenium rich feed to the hens. Among all micro-elements, selenium is one of the most essential micro-nutrient because it plays very vital function in our body. Selenium enriched eggs were first developed in the Scottish Agriculture College in 1998 by the use of supplementation of organic selenium in the form of Se enriched yeast into hen diets. The selenium exists in the eggs mainly in the firm of selenomethionine (Sc-met). Selenium is an important constituent of a number of functional seleno-proteins which is mandatory for normal health that may come from different sources like that bread and cereals, fish, poultry and meat. Supplementation of selenium in eggs can decrease the incidence of cancer. It was also reported that the supplementation of selenium may helps in betterment of semen quality in sub-fertile men and enhances the probability of successful conception. Addition of selenium in the eggs may play certain vital roles such as:

• Selenium supplementation helps in reduction of arthritis, cancer, cataract, cholestasis, cystic fibrosis, diabetes, immunodeficiency, lymphoblastic anaemia, macular degeneration, muscular dystrophy
• It may also help in the protection of one of the most dangerous disease of the world i.e., cancers. It also helps in decreasing the risk of DNA damage that is associated with cancer.
• Its supplementation can also improve blood fluidity by metabolic modification of lipoproteins which may provide and additional protective factor against cardio vascular disease development
• Se supplement may provide a safe and convenient way through rising antioxidant protection in elderly individuals, particularly those at risk of ischemic heart diseases, involved transient periods of

myocardialhypoxia

• It has beneficial effects in the conditions such as asthma, rheumatoid arthritis etc.

• Selenium enriched eggs can also reduce the risk of osteoporotic hip fracture in elder subjects

• Selenium also helps the conversation of thyroxin (T4) to the biological active compound i.e., in the triiodothyronine (T3) which plays vital role in the body

Iodine-enriched designer eggs:

In developing country like India, Africa, China and in many other countries of the world, some people are suffering from iodine deficiency diseases therefore iodine enriched eggs could be a good source of iodine in human diet. A typical egg of this type includes approximately 700 µg iodine. Eggs enriched with iodine can also reduce plasma cholesterol in humans and laboratory animals. On the basis of clinical trials conducted by Garber *et al.* (1993) showed that ingestion of one iodine-enriched egg a day for several weeks is relatively safe and devoid any significant adverse effects in healthy individuals. However, these eggs were not effective when used in low fat and low cholesterol diet by hyperlipidemic people. There are some indications of anti-inflammatory and anti-allergic properties of such eggs. To avoid this situation iodine should be enriched with vitamin E in the eggs.

Development of an egg enriched with Omega-3 PUFA, selenium, carotenoids and vitamin E

By manipulating the feed of laying hens it is possible to enhance the levels of Se, vitamin E, lutein and DHA. A single designer egg could therefore contain 50% of the RDA of Se, 100% of the RDA of long chain n-3 PUFAs, and 150% of the RDA of vitamin E. It would also supply 1.91 mg lutein.

The major advantages of the combination of DHA and anti-oxidants in the egg yolk are:

1. Vitamin E, lutein and Se protect DHA from oxidation during absorption and metabolism thereby preventing a 'fishy' taste formation;

2. Egg yolk lipids are necessary for the efficient absorption of vitamin E and lutein in human intestine (6 g lipids in the egg yolk is sufficient amount of lipids needed for an efficient absorption of vitamin E and lutein in the human intestine)

3. Lutein interacts with vitamin E and phospholipids, increasing the yolk's anti-oxidant potential and improving egg storability.