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Modified or Enriched Eggs: A Smart Approach in Egg Industry: A Review

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ABSTRACT

The modern desire of the health conscious people is functional food. Eggs are considered as complete food with most of the nutrients required for well beings. But the worries are related to the cholesterol content found in the egg. In addition, to the nutrients already available in the egg if we can alter or incorporate certain health beneficiary nutrients then these eggs will be the choice of food for health conscious peoples and it can also reduces the chances of occurrence of certain diseases. By the modification or enrichment in eggs we can obtain the eggs like low cholesterol eggs, omega-3 enriched eggs, vitamin enriched eggs, mineral enriched eggs, pigment enriched eggs and many more types of the modified or enriched eggs can easily be obtained for the specific proposes. The manuscript also contains some pros and cones of these eggs related to organoleptic qualities and its market related issues.

Key words: Eggs, modified eggs, omega-3 fatty acids, conjugated linoleic acid, vitamins, minerals

INTRODUCTION

In present scenario consumers are very much conscious about their health as a result demands of functional foods world wide increasing day by day. The optimistic views of increasing demand of the functional foods are also supported by number of institutions and health related organisations such as the American Dietetic Association (Hasler *et al*., 2004). An investigation conducted by Gilbert (2000) concluded that eggs are healthier and quality food with the draw back of high cholesterol contents. But the amount of cholesterol that comes from eggs much lesser than the quantity of cholesterol synthesized by the human body. The internal component of eggs can simply be transformed by the simple techniques like feeding etc. (Singh *et al*., 2010). The eggs can also be fortified with other nutrients i.e., iodine, fluorine, manganese, selenium, vitamins-B complex, vitamin E, ginseng and Conjugated Linoleic Acids (CLA). However, the fortification of various nutrients in an egg is solely dependent on nutritional manipulation of the laying hens ration (Ahmed and Abdelati, 2009; Singh and Sachan, 2010). These eggs are also capable to capture the market by changing their health status and appealing to a segment of the consumers who are willing to pay for these modifications in the eggs.

Modified or enriched 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 byproduct. However, modified fat content of the eggs are marketed as a reduced amount of

cholesterol, less saturated fat, elevated amount of omega-3 fatty acid, higher vitamin B content and high amount of iodine. The level of cholesterol in modified fat eggs is 190 mg per egg in comparison to 215 mg in generic eggs and saturated fat content 1 g in generic egg. 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 (Watkins, 1995). Now a day's small numbers of eggs are marketed as hormone free. This kind of report may be confusing to the customers in view of the fact that all eggs are obtained from hens that are not given hormones (Anonymous, 1999).

Pasteurization was initially used for the sterilization of liquid egg products; however, the technology to pasteurize a whole shell egg is relatively new. The process involves heating eggs to specific temperatures in water baths designed to heat the egg destroys pathogenic bacteria but not enough to coagulate the proteins. The eggs are held in water baths for a longer period carefully under controlled temperatures. The eggs are then cooled and packaged. Another newer technology in this field is the use of the irradiation. The FDA approved irradiation for treatment of shell eggs came into existence in 2000 but till date no irradiated eggs has been introduced in the consumer market.

Modified or enriched eggs: Egg is most excellent vehicle to incorporate numerous health promoting components. In the beginning of Cruickshank (1934) has testified that the fatty acid composition of egg may be modified by dietary manipulation of the feed. In the late 80s Sim Jany and their associates in the University of Alberta, Canada have combined those concept together and developed a designer egg which was rich in 3 n fatty acid as well as antioxidants. They have been patented this egg as professor Sim's designer egg. Afterward in Australia, Farrell (1998) produced another type of modified egg that was good source of folic acid and iron which was good for anaemic patients. In Canada, Leeson and Caston (2004) produced an egg which was fairly high in Lutein content as compared to the generic egg. These modified eggs act as retinal tonic by preventing Macular Degeneration and Retinitis Pigmentosa.

In India, Narahari *et al.* (2004) has build up a Herbal Enriched Designer Eggs (HEDE) which was not only rich in n-3 PUFA but also had vit-E, Se, carotenoids, certain B-complex vitamins and trace minerals. Theses eggs were also rich in several herbal active principle like allicin, betaine, eugenol, lumiflavin, luetin, sulforaphane, taurine and a lot of more active principle depending on herb fed to the hen. The modified eggs have 25% less cholesterol in their yolk as compared to the ordinary eggs or generic eggs. There are several techniques by which we can produce the modified or enriched eggs for different specific purposes.

Herbal designer eggs: Eggs are the most excellent vehicles to incorporate several health-promoting components in it (Singh and Neelam, 2010b). Herbal enriched eggs can be produced by the incorporation of herbal active principles like, allicin, betaine, eugenol, lumiflavin, lutein, sulforaphane, taurine and many more active principles of the herbs, depending upon the herbs fed to the hens (Table 2). Moreover, these eggs had about 25% lesser cholesterol in their yolks, compared to ordinary eggs. Feeding such HEDE to human volunteers has resulted in significant reduction in their Triglycerides (TG) levels, increased the good HDL cholesterol, improved immunity and haematocrit. Active ingredients present in herbs/herbal enriched functional eggs and their function in relation to human health are presented in Table 1.

Table 1: Active ingredients present in herbs/herbal enriched functional eggs and their function in relation to human health (Narahari *et al*., 2004)

Herbs	Principle active ingredients in herbs	Benefits in relation to human health
Garlic, onion and their leaves	Allicin, Allylic sulfide	Lower LDL cholesterol as well as anticarcinogenic properties
Sugar beet, grape pulp	Betaine	decrease plasma homocysteine, which ruptures arterial walls
Spirulina, marigold petals, alfalfa, red pepper	Carotenoid pigments	Work as Antioxidant and anticarcinogenic
Basil leaves	Eugenol, eugenic acid	Having Immunomodulator properties
Turmeric powder	Flavonoid compounds	Antimicrobial as well as antioxidant
Bay (curry) leaves, Marigold petals	Lutein	Antioxidants, Improves vision
Tomato pomace, grape pulp	Lycopene	decreases LDL (bad) cholesterol, antioxidant, anticarcinogenic
Citrus pulp	Nirangenin	Diminish LDL cholesterol
Flax seed, canola, fish, oils insects, worms	O-3 PUFA	Decreases LDL cholesterol, hypertension, angina and atherosclerosis
Seeds, weeds, legumes fenugreek	Phytosterols	Enhance HDL (good) cholesterol, decrease blood sugar
Quercitin, Luteolin, Diosgenin, citogenin	Fenugreek, spices	Induce insulin secretion, antimicrobial and tonic activity
Brewery waste, yeast, fermented products	Statin	Reduces LDL cholesterol
Broccoli, cauliflower, cabbage, radish leaves, waste	Sulphoraphane	Having both Anticarcinogenic and antioxidant properties
Milk, eggs and meat products	Taurine	Impede atherosclerotic plaque formation
Brans	Tocotrienols	Decrease LDL cholesterol

Table 2: DHA enhancement in eggs depending on dietary oil supplementation

Addition of oils in diets	Level of DHA enhanced (mg)	References
Flax seed oil	74-83	Jiang *et al*. (1991), Jiang and Sim (1993) and Maurice (1994)
Herring meal (12%) in the diet	100	Nash *et al*. (1995)
Menhaden oil (1.5%)	106	Marshall *et al*. (1994)
Menhaden oil (3%)	160-178	Hargis *et al*. (1991) and Van Elswyk *et al*. (1992)
Tuna orbital oil (0.5%)	180	Leskanich and Noble (1997)

Omega-3 fatty acid enrichment eggs: The total amount of the fat of the egg yolk cannot be changed by the feeding however, the composition of fatty acid can be altered by changing the type of oil used in hen diet. For that purpose different type of feeds are being used such as flax seed (Linseed), marine algae, fish oil and raps seed oil. These contents increase the omega-3 fatty acid content in the omega-3 fatty acid enriched eggs. Therefore, modified or enriched eggs production is mainly concentrated on the enrichment of egg lipids with n-3 fatty acids (Abubakar *et al*., 2007). The amount of the n-3 fatty acid is usually increased in eggs by one of two feeding methods (Leskanich and Noble, 1997). Primary one is the enhancement of egg by means of linolenic acid which is a precursor of DHA. For that purpose the hen's diet is usually enriched with flax seeds, linseeds or their corresponding oils. This lenoleic acid has a unique properties which is helpful in protection of heart diseases and the elevated intake of alpha-linolenic acid is protecting against fatal ischemic heart disease (Hu *et al*., 1999) and it has also found that due to significant enhancement of the n-3 fatty acid in the egg the death due to the cardiovascular disease is significantly reduced (De Lorgeril *et al*., 1994). On the other hand the health benefit of modified eggs can be limited because the conversion of linolenic acid into DHA in human body is not forever

effective particularly in elderly and children and almost all health promoting properties of n-3 fatty acids are correlated with DHA (Lopez-Bote *et al*., 1998). For that reason the addition in the hen's diet of preformed DHA, generally in the form of fish (menhaden, herring or tuna) oil, is a more promising way though this can be associated with a prominent fishy taste in the egg yolk (Van Elswyk *et al*., 1992).

Advantages of omega-3 fatty acid enriched eggs:

- On supplementation of omega-3 fatty acid may decrease the risk of heart disease by 50-70% (Hee-Kum, 2000)
- It is also reported that omega-3 fatty acid is helpful in increasing development of brain tissue in pregnant women and children
- It is also helpful in improvement of oxygen supply to the tissues
- It helps in increase of brain function
- Give relief in the treatment of Rheumatoid arthritis
- It improves skin and relieves arthritis
- Helpful in curing from inflammatory disorders and improve immune responses

The generic egg has only 60 mg omega-3 fatty acid as compared to an omega-3 enriched egg, which may have level as high as 350 mg (Scheideler and Lewis, 2002). However, there are a number of drawbacks reported for both consumers as well as producers. For producers point of view it involves increasing the cost of production of the omega 3-enriched eggs while in relation to the consumers the utilization of the higher quantity of omega 3 fatty acid causes thinness in the blood of consumers as compare to the typical eggs.

Low cholesterol designer eggs: At present health conscious consumers are suffering from cholestrophobia thus the demand of low cholesterol eggs is very high which 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. Chowdhury *et al*. (2005) and EL-Khier *et al*. (2009) reported that the supplementation of dietary tamarind quadratically decrease with increase in dietary levels of tamarind level in serum cholesterol concentration while the concentration of the cholesterol in the yolk was unaltered. However, Kim *et al*. (2004) and Habibullah *et al*. (2007) reported that on the supplementation of the certain substances like pravastatin, lovastatin and simvastatin can decrease plasma cholesterol. Parker *et al*. (1999) reported significantly decrease (by 4 mg g^{-1}) the cholesterol content of the yolk comparatively to the control after supplementation of beta cyclodextrin @ 6% in the feed. Certain other compound also reduced the level of the cholesterol in the yolk significantly such as chromium, nicotinic acid, statin, garlic, basil (Tulasi) plant sterol, n-3 PUFA after the supplementation in the feed to the hen. 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.

Vitamin-E enhanced 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 (Shahriar *et al*., 2008). 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 odors

Pigment fortification of yolk: Fortification of eggs with carotinoid is the new concept in the field of the designer eggs. The pigment enriched eggs looking attractive to the consumers due to its beautiful nature of more intense yellow colour. Canthaxanthin is a carotenoid usually used for the production of pigment enriched yolk by the help of the feeding of the hen having diet high amount of the canthaxanthin (Grashorn and Steinberg, 2002). There are a number of other carotenoid which may be used for fortification in egg consist of lycopene (Kang *et al*., 2003). These carotinoid pigments are naturally obtained from different sources such as marigold, chilly or corn (Ebrahim Nezhad *et al*., 2008). Blue green algae is the another source of carotenoid which is basically high in protein content but also provides certain pigment that is known as spirulina pigment and can be utilized for enhancing the carotenoids content in the egg yolk. Normally carotenoid in egg yolk of poultry are of hydroxyl compounds which is called xanthophylls (Edem, 2009). While lutein and zeaxanthin are the two most recurrent xanthophylls found in egg yolk. The beneficial effects of pigment enrichment in the yolk include:

- It assists in preventing macular degeneration
- It is responsible for attractive color of yolk
- It acts as antioxidant and anticarcinogenic agent
- Lutein is responsible for safeguard to the retina

Pharmaceutical designer eggs: Now a days, researchers are producing genetically modified chickens through the genetic manipulation which are capable to produce certain pharmaceutical compounds and these compounds can be harvested through eggs i.e., insulin which are used for treatment of diabetes. Other techniques are also adopted for the development of antibody enriched eggs. For that the hens are given an antigen and after its administration, hens develops antibody against the antigen which are then concentrated in eggs. This technique can be further expended for development of antibodies in the eggs and through which modified eggs will be able to treat the patients against snake venoms etc.

Immunomodulating eggs: The eggs naturally contains certain specific compound like lysozyme (G_1-globulin), G_2 and G_3-globulin, ovomacro 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. These eggs have not only high in nutritional value but also good immunostimulant and antiviral properties. Like other component of eggs modification the levels of I gY like immunoglobulin's in the egg can be improved by dietary manipulation. The properties of the immunomodulating of eggs can further improve the eggs by use of omega-3 fatty acid and antioxidants. After feeding of Tulasi @ 0.3-0.5% dietary level the result showed highest ability to boost the IgY level. Certain other herbs like rosemary, turmeric, garlic, fenugreek, spirulina, ashwagandha are also possessing immunomodulating properties so by the use of that kind of herb in the feed of the hen also improve the efficiency of the immunomodulating properties of the eggs.

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 (Al-Massad *et al*., 2011). Normally a hen egg contain almost about 53 μg iodine/100 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 at that level of KI in the feed does not affect the performance of the hen. It can increase the iodine content from 26-88 μg in 60 g hen egg tremendously (Rottger *et al*., 2008; Durmus *et al*., 2010).

Selenium enriched designer eggs: Now a days, selenium enriched eggs are available in more than 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 (Hassanien, 2011). Selenium enriched eggs were first time developed in the Scottish Agriculture College in 1998 (Surai, 2000) by the use of supplementation of organic selenium in the form of Se-enriched yeast into hen diets. The selenium exist in the eggs mainly in the form of selanomethionin (Se-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 (Reilly, 1998; Hattingh *et al*., 2008). Supplementation of selenium in eggs can decrease the incidence of cancer (Blot *et al*., 1993; Clark *et al*., 1996). 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 (Scott *et al*., 1998). 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 (Surai, 2000)
- It may also help in the protection of one of the most dangerous disease of the world i.e., cancers (Papp *et al*., 2007; Squires and Berry, 2006; Whanger, 2004)
- 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 (Abdulah *et al*., 2006) 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 myocardial hypoxia (Venardos *et al*., 2007)
- 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 (Zhang *et al*., 2006)
- Selenium also helps the conversation of thyroxin (T_4) to the biological active compound i.e., in the triiodothyronine (T_3) 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 (Garber *et al*., 1993). Eggs enriched with iodine helps in increase of iodine albeit and also increased iodine excretion (Kaufmann *et al*., 1998). Eggs enriched with iodine can also reduce plasma cholesterol in humans and laboratory animals (Tanaami *et al*., 1985). On the basis of clinical trial 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 (Garber *et al*., 1992). There are some indication of anti-inflammatory (Isono *et al*., 1993) and anti-allergic (Kohno *et al*., 1986) properties of such eggs. To avoid this situation iodine should be enriched with vitamin E in the eggs (Garwin *et al*., 1992).

Organoleptically improved modified eggs: The effects of the cooking on eggs change neither the fatty acid profile of the eggs nor the functional properties of the eggs. Panelists' be able to simply distinguish n-3 enriched eggs from normal when knotted but not when hard cooked (Van Elswyk *et al*., 1992). However, linseed fed poultry showed the slight off-flavour in eggs (Caston *et al*., 1994). If hens are fed with flax seed at the rate of 15-20% of the hens diet then a fishy or fish-product liked flavour was also reported in that kind of the eggs (Ferrier *et al*., 1994; Jiang and Sim, 1994). In general, the acceptability of these eggs are diminished in relation to the aroma and flavor both by Leeson *et al*. (1998) with the elevated (>10%) levels of flax seed in the birds' diet. These off-flavours can concealed by the use of flax seed in combinations of antioxidants in the hen's diet. Omega-3 fatty acid-enriched eggs from hens fed 1.5% menhaden fish oil or 5% flax seed have minimum effects on consumer acceptance as compared to marketable table eggs (Scheideler *et al*., 1997). There were other reports indicating absence of the effect of egg enrichment with n-3 fatty acids on their organoleptic quality (Cloughley *et al*., 1997; Maurice, 1994; Marshall *et al*., 1994).

Cooking properties of omega-3 enriched eggs such as emulsification capacity, hardiness and springiness of sponge cakes prepared by using these eggs do not alter as compared to the ordinary eggs (Leskanich and Noble, 1997; Singh and Neelam, 2010a; Salawu *et al*., 2007). In general, the development of the fishy taint might be the result of rancidity in n-3 enriched diet. However, if the oil is already oxidized antioxidants will not be able to reverse this process and the use of stabilized or micro-capsulated oils could substantially improve the situation. It has also been reported that cooking of n-3 PFU, as eggs have no effect on the fatty acid composition of the eggs (Van Elswyk *et al*., 1992) and also has no effect on storage of seven weeks at 25°C (Oku *et al*., 1996). However, the duration of storage characterized by increased susceptibility to oxidation of in n-3 enriched eggs are (Cherian and Sim, 1996) which can cause problems during egg storage and cooking. Fortification of egg yolk with vitamin E is an efficient means to resolve this problem (Cherian and Sim, 1996; Qi and Sim, 1998).

Commercial production of modified designer eggs: There are various types of modified or enriched eggs available in the shelves of supermarket in different countries. In UK there are free range eggs, organic eggs, free range organically produced eggs, Columbus eggs etc., eggs improved in iodine content in Japan or DHA in Canada etc. are some of the examples. The Pilgrim's Pride

Company of North America is a largest producers of poultry products, introduced 'Eggs Plus' with an increased level of vitamin E and omega-3 fatty acids. Identical eggs are produced by Gold Circle Farms (contain 150 mg DHA and 6 mg vitamin E, Colorado, USA) and Omega Tech (USA) and these eggs are known as Gold Circle Farms Eggs. Omega Tech launched the sale of DHA eggs in Germany, Spain, Portugal, Belgium, Norway and Andorra. They are sailing the modified eggs by different names: Omega DHA eggs (Germany), Brudy eggs (Spain, Portugal and Andorra), DHA Food Products-Benelux (Belgium) and DHA pluss (Norway). DHA-enriched eggs were recognized with the "Most Innovative Finished Food Product Award" in 1996 at the annual Food Ingredients Europe Conference in Paris. A survey conducted in 5 major Texas cities with over 500 consumers indicated that 65% of consumers were willing to purchase n-3 fatty acid-enriched table eggs and, of these, 71% were willing to pay an additional $0.5 per dozen (Marshall *et al.*, 1994). Such types of market are yet to develop in India but the peoples of metropolitan cities are very much keen to purchase such types of the products. Suguna poultry farm has taken the step in this direction and launched a range of designer eggs for beauty conscious consumer, as well as person affected with diabetes and heart disease.

CONCLUSION

If we want to develop an industry with modified or enriched eggs it is utmost important to consider the safety and quality of such products. In additional enriched or modified eggs should be guaranteed and consistent product quality so that consumers should be sure of receiving in these eggs. The indications and information's in this regards must be stated on the packaging. The future of such eggs may be with the modified or enriched eggs as discussed above in addition to Vitamin-C enriched eggs, Fiber enriched eggs, choline enriched egg etc.

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