

Egg and its Industrial Uses

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For centuries, eggs were known to be highly nutritious food, perfectly packaged, providing the most complete and the highest-quality proteins; a 2 to 1 ratio of unsaturated fatty acids to saturated fatty acid and further as an excellent source of iron, phosphorous and other minerals and all the vitamins with the exception of vitamin C. The adverse publicity the egg has' received due to its cholesterol content is also now withdrawn due to growing recognition that dietary cholesterol does not necessarily affect serum cholesterol. The emphasis is now growing again on the eggs' positive attributes.

Multi-functional attributes of eggs have been well recognized and have contributed to their continuing use as a non-nutrient ingredient in many food systems. The whipping, gelling, coagulating, emulsifying, foaming, adhesive and clarifying properties of the egg components are utilized for varied purposes in the food industry. Efforts are now made to capitalize on the unique components in eggs for health applications. Utilization of the egg as a carrier of enriched nutrients and the isolation of valuable components from the egg are receding higher attention. Ovo nutraceuticals and bio-medical products (OVN/ BMP) represent new opportunities for the egg-industry

Immunoglobulins

The importance of eggs as a source of specific antibodies is well known. Egg yolk contains 8-20 mg of immunoglobulin (IgY) per ml. However, the major problem in

isolation is the removal of lipids which are present in high concentrations. Several methods had been developed by employing water dilution and solvent extraction to separate yolk plasma proteins from the granules and lipids. Hen serum IgG is transferred to its egg yolk and provides its offspring with acquired immunity. Thus, it is possible to obtain pathogen-specific egg yolk antibodies from eggs laid by hens immunized against the specific antigens. Egg yolk immunoglobulin (IgY) content of chicken eggs is about 100-150 mg/egg (Rose et al.,1981)), an amount which is remarkably higher than the antibody (IgG) content in the same volume of mammalian serum or milk.

Lysozyme

Lysozyme is extracted from egg white. Lysozyme is used in eye drops and various cold remedies. Lysozyme is also utilized as a preservative for cheese. Lysozyme is a naturally occurring enzyme which was discovered and characterized in the 1920s as having antibacterial activity against gram-positive bacteria. It attacks the cell wall of gram-positive bacteria leading to cell lysis and death. It is present in many secretions and tissues such as human tears, saliva and mother's milk, as well as viruses, bacteria, phage, plants, birds, eggs, insects, reptiles and other mammalian fluids. The most readily available source is the white of hen's eggs. Lysozyme is effective against a number of bacteria responsible for infections

of the human body and for the spoilage of various foods.

One of the most important commercial uses of lysozyme is in the ripening of certain European-type cheeses. Lysozyme inhibits the growth of *Clostridium tyrobutyricum* - a bacterium, which can be present as a contaminant in milk. The presence of *Clostridium tyrobutyricum* in the developing cheese has the effect of producing butyric acid, which causes an "off-flavour", and excess hydrogen and carbon dioxide, which causes internal pressures leading to slits and cracks. Lysozyme has been used for over a decade in many European countries and has received GRAS (Generally Recognized As Safe) status from the Food and Drug Administration of the USA.

A more recent use of lysozyme is in wine preparation as a substitute for sulfites. The lysozyme inhibits lactic acid bacteria and development of malolactic fermentation can be controlled. This leads to better organoleptic (colour and taste) properties and a better tolerance by those consumers, who are sensitive to sulfites. Lysozyme can also form synergies with other antimicrobial compounds such as nisin and the resultant compound will attack *gram-negative* food spoilage bacteria.

Sialic acid

Sialic acid has been isolated and crystallized from chicken egg white and the principal component appears to be identical with the sialic acid from *Escherichiac oli*,

which is N-acetylneuraminic acid. All of the sialic acid in egg white appears to occur bound to proteins. The ovomucin and ovomucoid fractions contained approximately three-fourths of the total sialic acid in the egg white. The remainder was found in the flavoprotein and the unidentified constituents. The structural components, chalazae and yolk membranes, contained approximately 10 times the concentration of sialic acid found in whole egg white, but no evidence was obtained for a major role of sialic acid in the maintenance of the physical structure. Sialic acid derivatives from egg yolk are known to be involved in brain (neuron) functions and are also important in protecting infants from various diseases. These sialyloligosaccharides attract attention from pharmacological and food chemical industries because of their potential biological functions.

The sialic acid is the substance liberated from the inhibitors, and probably from the erythrocytes, by preparations of the active virus. The neuraminidase enzymes, which also liberate sialic acid from these substances, have been isolated and purified from *Vibrio cholerae* and *Clostridium perfringens*. The ovomucoid fraction, which also contains sialic acid, possesses inhibitory activity against trypsin but no inhibitory activity against viral hemagglutination.

Sialyloligosaccharides have been shown to be very high in mothers' milk at the time of parturition, suggesting that they play a significant role in the defense mechanisms against diseases such as pneumonia, diarrhoea, gastritis and ulcers. Sialyloligosaccharides can be extracted from egg yolk. Hens eggs are recommended dietary

source of sialic acids. Hens eggs contain sialic acid in such amounts that they are thought to be a potential source for the industrial – scale isolation of sialic acid (Koketsu et al. 1992)

Nutraceutical

The industry is presently geared in production of speciality eggs that have higher or enriched levels of certain nutrients already present in the eggs or lower levels of certain other nutrients, which are considered unhealthy for some reasons. Such eggs are called in different names as "Functional Eggs", "Diet Eggs", "Designer Eggs" or "Omega-3 Enriched Eggs". Functional foods are basically defined as foods or food ingredients that may enhance health through the provision of a physiological benefit beyond traditional nutrients. Nutrient substances when included in diets over and above normal requirements with the view to manage health impairment are referred to as Nutraceuticals.

Omega - 3 fatty acids

Omega, -3 fatty acids are derived largely as EPA (eicosapentaenoic acid) and docosahexaenoic acid (DHA) from fish oils and as ALA (alpha-linolenic acid) from plant oils. Under natural conditions, the chicken egg has an omega-6 / omega-3 ratio of 1 :3. The dose-dependent action of dietary EPA and DHA in reducing plasma triglyceride level is well documented. There is also strong evidence that a lower ratio of omega-6 / omega-3 fatty acids is more desirable in reducing the risk of many of the chronic diseases like cancer, cardio-vascular disease, inflammatory and autoimmune diseases. Omega-3 fatty acids viz., linoleic, eicosapentaenoic and docosahexaenoic acids reduce

hypertension, LDL and VLDL cholesterol and triglyceride levels, prevent thrombosis, platelet aggregation, angina, atherosclerosis and stroke. Suh (2004) recommended that to prevent functional disadvantage in retina and brain, omega-3 fatty acids are to be included in infant formula. Sujatha (2002) observed that incorporation of 2% fish oil, 10% sardine fish or 4% mustard oil in layer mash significantly improved omega-3 fatty acids' content in egg yolk by 9, 10 or 7 times than normal level.

Selenium

Inadequate selenium consumption is associated with poor health and development of various viral and bacterial diseases. Dietary supplementation of selenium was found to decrease cancer mortality 2-fold. In many countries all over the world, human food ingredients do not provide sufficient selenium. Selenium in high dose is also toxic. Hence, supplemental level of selenium should not exceed physiologically required amounts. Dvorska et al. (2004) concluded that Se-enriched eggs could be used as an important delivery system of selenium for humans. Egg selenium could be easily increased, when organic selenium is included in the hen's diet at a level to provide 0.4-0.8 ppm Se. Inorganic selenium in the form of selenite or selenate has low efficiency of transfer to the egg.

Xanthophylls

Lutein, an yellow carotenoid has been used as colouring agent for egg yolk and broilers. Lutein is also an important cellular antioxidant. Lutein and zeaxanthin help in preventing macular degeneration and cataract. They help in filtering out the harmful effects of blue light that destroys the macular region in the back of

the eye. Lutein could be protective against some forms of cancer and cardiovascular diseases by reducing oxidative stress. Lutein is also inversely related to progression of atherosclerosis. The lutein content of the egg is related to that of the layer's diet. Egg currently contains 0.5 mg lutein, which can be increased through dietary manipulation to 4-5 mg / egg. This lutein is highly bio-available for human nutrition.

Vitamin E

Vitamin E is an important component of antioxidant defenses and in many cases, human diets are deficient in this antioxidant. Vitamin A and D are toxic for chickens, when added into the diet at very high levels. Vitamin E and lutein can be added at high doses without any side effects. Vitamin E, carotenoids and selenium do not affect egg taste; they might help in prevention of fishy taste appearance in omega-3 eggs. Egg enrichment with lutein could be beneficial in terms of consumer preference of deep coloured egg yolk. Vitamin E, lutein and Se are quite stable during egg boiling or frying. Commercial products of vitamin E (DSM nutritional products, BASF, etc.), organic selenium (Altech, Inc.) and lutein (Kemin etc.) are available in the market for incorporation in hen's diet.

Folic Acid

The need to increase folate intake in human diet is growing. Increased folate intake reduces the incidences of women having babies with neural tube defects and miscarriages. Folate also reduces the incidence of adverse cardiovascular events. Attempts are made to increase intake of this vitamin in the human diet through consumption of folate enriched ~gg. Addition of 4 mg / kg

crystalline folic acid was found to be the optimal level of supplementation needed to yield maximal egg folate concentration -increased from 20 mg to 50 mg (House *et al.*, 2004)

Others

1. Genistein is a potent phytoestrogen in soybean, particularly in the protein fraction. Many of the current nutraceuticals in the market for aging women contain significant concentration of soy isoflavones. Ottinger *et al.* (2004) demonstrated, that the quail accumulate genistein in their egg yolks by feeding capsules containing 50g genistein.

2. Conjugated linoleic acid (CLA) is a group of isomers of linoleic acid. Feeding a diet containing 2 % CLA to hens resulted in over 5.5 CLA / 100g fatty acid\$ or approximately 300 mg. CLA egg. Dietary CLA increased the egg saturated fatty acids with a concomitant reduction in monounsaturated fatty acids (Cherian, 2004).

3. Lecithin from egg yolk is a rich source of phosphatidylcholine (PC), which is a major phospholipid component of the cellular membrane. PC also serves as a precursor of acetylcholine, a neurotransmitter. Egg PC in conjunction with vitamin B may slow the progress of, or even prevent Alzheimer's disease.

4. Choline is a vitamin, research on which indicates that it plays an essential role in the development of brain function and memory. Lactating mothers are recommended to increase their dietary choline intake to reduce the severity of memory defects later in life.

Medical and Pharmaceutical

Fertile eggs are used to manufacture many vaccines

(including influenza shots), as a source of purified protein and as an aid in the preservation of bull semen for artificial insemination.

In some areas of the world, such as China, India and Eastern Europe, eggs have been used for centuries as the base for health potions. Today a number of nutraceutical uses of eggs are being employed and scientists are studying potential future egg benefits. Current applications include:

Lysozyme, an egg white protein, is used as a food preservative and as an antimicrobial agent in pharmaceutical products. (Nature also provides lysozyme in human tears and saliva for infection prevention.)

Avidin is an egg white protein and biotin is a vitamin found in egg white and, to a much greater extent, in egg yolk. Avidin-biotin technology is being used in various medical diagnostic applications such as immunoassay, histopathology and gene probes.

Sialic acid, an amido acid, has been shown to inhibit certain stomach infections.

Liposomes, fatty droplets found in eggs, are used as a controlled delivery mechanism for various drugs.

Immunoglobulin yolk (IGY), a simple egg-yolk protein which has immunological properties, is used as an anti-human-rotavirus (HRV) antibody in food products.

Phosvitin, a phosphoprotein found in egg yolk, provides antioxidant benefits in food products.

Choline, a B vitamin combined with lecithin in egg yolk, is important in brain development

and is used to treat certain liver disorders. Eggs are one of the best food sources.

Ovolecithin, a phospholipid found in egg yolk, has a high proportion of phosphatidylcholine and contains fatty acids – such as arachidonic acid (AA) and docosahexanoic acid (DHA) – which have been shown to improve visual activity in infants and to improve fatty-acid status. Egg lecithin has both emulsifying and antioxidant properties and, beyond its usefulness in keeping the oil and vinegar of mayonnaise in suspension, it's used chiefly in medicine.

Shell-membrane protein is being used experimentally to grow human skin fibroblasts (connective tissue cells) for severe-burn victims and, in Japan, is being used in cosmetics.

Biomedical uses

1. Specific Pathogen Free (SPF) Eggs

SPF poultry are birds, which are demonstrated to be free of a wide range of micro-organisms, capable of producing diseases in poultry like viral, bacterial or protozoan diseases. SPF poultry are maintained under Filtered-Air-Positive-Pressure (FAPP) poultry housing systems under critical bio-security measures. SPF eggs are free from listed pathogens (viral antigens) and antibodies specific to them.

SPF eggs are used in production of human and avian vaccines and virus seed stocks (human and veterinary). They are also used in quality control of diagnostics and also in avian disease research viz. ELD₅₀, EID₅₀, tissue culture, virus cultivation and virus titration etc.,

2. Egg Shells

The use of egg shells as a dietary source of calcium for humans has been investigated. A powdered, purified product has been tested in fortification of breads and confectioneries, fruit drinks, crackers, condiments.

Egg shell calcium has been tested as an oral phosphate binder for use in low phosphate diets for e.g., patients suffering from renal failure.

3. Egg Shell membranes

The protein from egg membranes adheres to and grows human skin fibroblasts and increases the production of type III collagen, which is rich in the skin of infants, presumably softening the skin. This egg membrane protein is being used as an ingredient in many cosmetics.

4. Antigen specific immunoglobulins (IgY)

By challenging the hen with a specific antigen (e.g. *Escherichia coli*), the hen will utilize her natural system to create antibodies which will not only protect her, but also will be passed on to the eggs she lays. Humans or other monogastric animals that eat these antibody enhanced eggs will then have an increase in this particular antibody and an increased ability to counteract the effects of the original antigen: a very effective method of administering vaccine to a population. This is known as passive immunity and it can provide immediate, but short lived protection against specific diseases. This is in contrast to active immunity, which primes the body to make its own antibodies and confers life-long immunity.

This new IgY technology opens new potential market applications in medicine, public health, veterinary medicine and

food safety. A broader use of IgY technology could be applied as a biological or diagnostic tool, nutraceutical or functional food development, oral-supplementation for prophylaxis, and as pathogen-specific antimicrobial agents for infectious disease control. This concept could serve as an alternative agent to replace the use of antibiotics, since today, more and more antibiotics are less effective in the treatment of infections, due to the emergence of drug-resistant bacteria.

Successful results have been obtained by feeding piglets (and rabbits) egg yolk powder containing anti-*E. coli* antibodies. This serves as a protection against the pathogenic effects of *E. coli* which causes usually fatal diarrhoea in early weaned piglets.

IgYs from eggs have been used in foods e.g., passive immunization by oral administration of IgY has been effective in preventing dental caries and rotaviral diarrhoea. Some food products e.g. candies, chocolates and gums containing anti-*Streptococcus mutans* (a cause of tooth decay) have been used in Japan for oral care.

Egg antibodies have also been successfully tested to provide immunity against snake venom in humans, mastitis in cows, *Pseudomonas aeruginosa* in cystic fibrosis patients and *Edwardsia tarda* infection of Japanese eel.

Tests indicate that IgYs can be used to counteract some *Salmonella spp.*

Egg antibodies have also been extracted and used in diagnostics and affinity chromatography applications e.g. antibodies directed against ochratoxin - a mycotoxin

widespread in foods and feeds - can be used to detect the presence of ochratoxins. Using transgenic chicken, research is also being done in collaboration with a number of companies and research establishments .. the produce **egg** antibodies, which will fight hepatitis; melanoma and other cancers.

5. Human Serum Albumin (USA)

Work is underway to genetically alter chickens so that they produce eggs containing a large quantity of human serum albumin (HSA), a protein used in saline drips in hospitals. Currently the protein is taken from human blood plasma, but this is very costly. It is estimated that a flock of 10,000 layers could produce 5% of the world's demand for HSA.

6. Conalbumin and Ovalbumin

• Ovotransferrin or Conalbumin is another protein of egg white, which has been used as an antimicrobial agent in food applications. More recently, research has been in the treatment of HIV and in preventing periodontal disease. Lagarde reports that in Japan, immobilized ovotransferin has been used to remove iron from drinking water, as well as water for brewing, and a company in the Netherlands has filed a patent for a nutraceutical drink containing ovotransferin.

Ovalbumin is the predominant protein in egg white and is utilized in cell culture systems and in the diagnostic industry where enzymes and hormones require stability to maintain their

functional integrity. It acts as a stabilizer, binding ,protein, transport protein and growth media supplement.

Other Uses

• Avidin from egg white has been used for affinity chromatographic columns for various analytical methods.

• Egg yolk contains a high level of lutein which has been shown to be a factor in prevention of age-related macular degeneration in the eye.

• Choline from egg yolk lecithin has been shown by some researchers to be a possible memory booster.

• Eggs are utilized as a culture medium in producing several vaccines used to treat various viruses.



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Egg yolk has been indicated to be beneficial to skin. Thus, egg yolk is added to shampoos, skin creams and other cosmetic applications.

- Antibodies from eggs may be used to treat various viruses.

- Egg yolk is used as a preservative for bovine spermatozoa used for artificial insemination.

Cosmetics

- Egg white has long been used as a facial. Egg yolks are used in shampoos and conditioners and, sometimes, soaps. Cholesterol, lecithin and some of the egg's fatty acids are used in skin care products, such as revitalizers, make-up foundations and even lipstick.

Animal Feed

- The excellent nutrition of eggs enhances various pet foods. Egg white is used as a protein reference in feeding laboratory animals. Eggshells from processing plants are often dried, crushed and fed to laying hens as a rich calcium source and high-quality protein source (from egg white left inside the shells).

Experiments

- Microorganisms bred in laboratories often grow better if a small amount of egg yolk is added to the culture medium.

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YEAST :

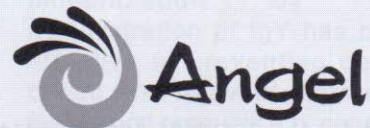
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Industrial Applications of Egg Components

S1. No.	Component	Applications
A.	Egg White Proteins	
1.	Ovalbumin	Key reference protein in bio-chemistry
2.	Ovokinin	Vasorelaxing function - in hypertension
3.	Ovotransferrin	Iron fortified food products, bactericide in treatment of enteritis in infants.
4.	Lysozyme	Anti-microbial in food products, food packaging films, to control microbial processes in cheese, beer and wine production
5.	Cystatin	Antimicrobial, prevention of cerebral haemorrhage
6.	Avidin	Binds biotin, used in molecular biology:--- affinity chromatography, ELISA
7.	Ovoinhibitor	Inhibits trypsin, antifungal, antimicrobial
B.	Egg Yolk Products	
1.	Egg oil	Cosmetics, aquaculture, pharmaceutical -- industry
2.	Specific antibodies	Prevention of specific diseases
3.	Liposomes	Sustained delivery of drugs
c.	Egg Yolk Lipids	
1.	Lecithin	Confectionery, snack foods, soaps, detergents, leather, paints, infant formulas, anti-oxidant
2.	Choline	Commercial infant formulations.
3.	Cholesterol	Infant formula (breast-fed infants)
4.	Sphingolipids	HDL - LDL
5.	Phosvitin	Prevention of osteoporosis
D.	Egg Yolk	
1.	Sialic acid	Brain function, protection for infants
2.	Sialic Oligosacchrides	Defense mechanism - infant formula
B.	Egg Yolk Pigments	
1.	Lutein, Zeaxanthin	Antioxidants - protection against macular degeneration
F.	Egg Shell Proteins	
1.	Egg shell membrane	Bacteriolytic enzymes - facilitates growth of normal skin
2.	Collagen (10%)	Skin and tissue replacement products
G.	Egg Shell Minerals	
1.	Egg shell powder	High Ca, strontium low lead, cadmium, mercury
2.	Egg shell calcium	Oral phosphate binder - in renal failure
3.	Egg shell carbohydrates	Cosmetics (moisturizer), osteoarthritis emulsifying agent
4.	Designer eggs	Nutraceuticals