

The 'super-egg'.

by Peter Surai

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Chicken's eggs have been eaten by humans since antiquity. No other single food of animal origin is eaten by so many people all over the world and none is served in such a variety of ways. The egg's popularity is justified not only because it is easily obtainable and has so many uses in cookery, but also because it is very nutritious.

From a nutritional point of view the wide use of eggs in the diet is understandable. Of the three macronutrients -- proteins, fats and carbohydrates -- the egg is composed largely of the first two. Its proteins are highly digestible and contain all the essential amino acids. The amino acid profile of egg proteins is similar to the ideal balance of amino acids needed by humans. Eggs also supply various minerals, some in significant amounts, and contain a range of vitamins. Eggs are also used in the cooking of a wide range of foods.

The major problem with eating a lot of eggs is cholesterol (see BIOLOGICAL SCIENCES REVIEW Vol. 13, No. 2, pp. 2-5). It was thought that egg consumption was associated with raised blood cholesterol levels, and thus was unhealthy -- reducing life expectancy. Because of health fears egg consumption in Britain has fallen in the past 5 years, from more than 3 a week per person to less than two a week. However, recent studies have shown that large numbers of eggs can be consumed over lengthy periods without any adverse changes to plasma cholesterol or other lipid components of the blood. Eggs could, therefore, be used to add important or scarce nutrients to our food in the same way that margarine is now enriched with vitamin D, or corn-flakes with iron (see BIOLOGICAL SCIENCES REVIEW Vol. 12, No. 5, pp. 38-40).

Free radicals and antioxidants

It is now recommended that people should eat at least two servings of fruit and three servings of vegetables daily. Most adults fall well short of these guidelines! One of the main reasons for these recommendations is the recent understanding that natural antioxidants play a crucial role in combating free radicals in the body (see BIOLOGICAL SCIENCES REVIEW Vol. 12, No. 1, pp. 18-21).

Free radicals are atoms, molecules or compounds containing one or more unpaired electrons. Free radicals are highly unstable and reactive and are capable of damaging molecules such as DNA, proteins, lipids and carbohydrates. The human body is under constant attack from free radicals (see Figure 1), formed as a natural consequence of the body's normal metabolic activity and as part of the immune system's strategy for destroying invading microorganisms.

Biological antioxidants are substances capable of reacting with free radicals (or the products of their reactions), converting them into less reactive molecules, thus preventing or delaying oxidation of biological molecules. Antioxidants thus limit the damage done by free radicals. Normally there is a balance between the amount of free radicals generated in the body and the antioxidants to protect against them. However, an excess of free radicals, caused by pro-oxidants or lack of antioxidant protection, can shift this balance -- a harmful situation (see Figure 2). Pro-oxidants are substances that could promote lipid peroxidation. For example, if iron is not bonded to protein (free iron) it can be a pro-oxidant.

For the majority of organisms on earth, oxygen is essential for respiration. However, it is not widely realised that free radicals derived from oxygen can damage all types of biological molecules. It is only the presence of natural antioxidants in living organisms that enables them to survive in an oxygen-rich environment.

Free radical formation is a biochemical mechanism involved in various diseases, including cardiovascular disease, some forms of cancer, cataracts, age-related degeneration of the retina, rheumatoid arthritis and a variety of neurodegenerative diseases. It is therefore important to balance oxidative damage and antioxidant defence in the human body. The best way of enhancing the antioxidant capacity is by increasing antioxidant levels in the diet to the optimum levels.

A range of different compounds in our diet possess antioxidant activities. Among them, vitamin E, carotenoids and vitamin C all act as antioxidants. Vitamin A is also an antioxidant but is less effective compared with vitamin E. The trace mineral selenium is also involved in antioxidant defence in the body since it is an integral part of the antioxidant enzyme glutathione peroxidase.

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Polyunsaturated fatty acids (PUFAs)

In recent years our understanding of how dietary fatty acids influence our metabolism has grown. Fatty acids are involved in energy metabolism, they are constituents of membranes and are precursors of hormones, but they also have specific regulatory functions through the synthesis of different biologically active compounds, including prostaglandins. Some are involved directly in regulating gene expression.

Evidence is accumulating that eating marine N foods rich in specific PUFAs (so-called omega-3 PUFA) has benefits in the prevention and treatment of cardiovascular disease, hyperlipidaemia, thrombosis, hypertension and in controlling the immune response. The low incidence of heart attacks among Greenland Inuits and Japanese fishermen and their families (who eat very large amounts of fish) are associated with high levels of omega-3 fatty acids in their diet. The typical 'Western' diet is not well balanced, containing too few antioxidants such as vitamin F, carotenoids and selenium, and it is often deficient in specific PUFAs.

Improving the diet

Vitamins, carotenoids and trace elements (such as selenium) can all be obtained as tablets or capsules, but it is generally thought that they are best obtained through eating a balanced diet. Antioxidant-fortified food, therefore, could be an important way of improving the diet.

When choosing foods that could be used to improve our diet it is necessary to take into account dietary preferences, eating habits and many other factors. Too much of a good thing may be harmful. Some nutrients, for example selenium, are toxic if eaten in excess. Therefore, the food chosen for improving the diet should be one that is likely to be consumed in moderate and stable amounts. High-temperature processing can destroy a range of nutrients, including antioxidants.

From eggs to super-eggs

Eggs have been chosen as a convenient delivery system for nutrients to improve our diets. The aim has been to produce a 'super-egg' enriched in four nutrients:

- * vitamin E (the most abundant lipid-soluble antioxidant);
- * lutein (one of the most important plant carotenoid pigments);
- * selenium, Se (a trace element);
- * DNA (the most important long-chain polyunsaturated fatty acid belonging to the omega-3 family).

The main concept used in the development programme was 'healthy eggs from healthy birds'. Hens were fed on diets containing natural feed compounds. Their food was enriched in the four nutrients.

The results indicated that these four nutrients are important for the health of both hens and humans. By manipulating the feed of laying hens it was possible to enhance the levels of Se, vitamin E, lutein and DNA in their eggs by approximately 8, 25, 15 and 6 fold respectively. The amounts of these nutrients delivered in a single super-egg are shown in Table 1.

Advantages of super-eggs

The major advantages of the combination of DNA and antioxidants in the egg yolk are:

- * vitamin E, lutein and Se protect DNA from oxidation during absorption and metabolism, preventing what would otherwise lead to formation of a 'fishy' taste;
- * egg yolk lipids are necessary for the efficient absorption of vitamin E and lutein in human intestine (6 grams of lipid in the egg yolk is exactly the proportion of lipid needed for efficient absorption of vitamin E and lutein in the human intestine);

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* Lutein interacts with vitamin E and phospholipids, increasing the yolk's antioxidant potential, thus increasing egg shelf-life;

* Se, as an integral part of the antioxidant enzyme glutathione peroxidase, protects intestinal membranes against lipid peroxidation during DNA digestion.

An important point is that two major antioxidant constituents of the egg, vitamin E and lutein, are stable during egg boiling.

Human dietary trials showed that eating an egg a day for 8 weeks had no significant effect on blood pressure and total lipid and cholesterol levels in plasma. On the other hand, the plasma concentrations of vitamin E, lutein and DNA increased significantly over the course of the experiment in volunteers who ate super-eggs. The control group showed no change in the concentration of these nutrients.

Therefore, the inclusion of a single super-egg per day in the human diet can almost double lutein consumption and can be considered as a reliable source of lutein without the seasonal variation that occurs in areas of the world where fresh vegetables are not always available. Inclusion of super-eggs into the human diet (3--4 eggs per week) would increase vitamin E consumption up to desirable levels. The super-egg can also deliver the recommended 200 mg of DHA per day per person and thus can be considered as an alternative additional source of very long-chain omega-3 PUFA in the human diet.

These eggs could also be valuable in improving the diets of pregnant women, the elderly and young children. Including the eggs in processed foods, such as mayonnaise and cakes, would increase their nutritional qualities. Super-eggs would be useful for people exposed to stresses such as radiation and extremes of temperature or humidity, since these conditions stimulate free radical production. The eggs could be important to people living in polluted areas (e.g. Chernobyl), in areas with very low temperatures (e.g. polar expeditions) and in other extreme conditions (e.g. submarine crews).

Conclusion

The super-egg is not just highly nutritional. It is also a good vector for the delivery of four essential nutrients vital for human health. A crucial feature of these designer eggs is the synergistic combination of omega-3 fatty acids with major antioxidants, vitamin E, lutein and selenium, as an important approach to the improvement of the human diet.

These eggs will not be able to replace vegetables and fruits as a major source of natural antioxidants, and fish products as a source of DHA, but they could substantially improve the diet, contributing significantly to the recommended daily intake of vitamin E, lutein, DHA and selenium.

Points for discussion

* Given that there is evidence that chickens fed on supplements to produce super-eggs are healthier than conventionally fed chickens, is it ethical not to feed these supplements to all chickens?

* How would you market super-eggs to a public largely wary of natural foodstuffs that have been 'tampered with'?

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Table 1

The composition of a super-egg

Nutrients in a super-egg	Amount (mg) per super-egg	% recommended dietary allowance	Similar amount provided by:

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Vitamin E	20	150	100 g corn oil 150 g margarine 300 g peanuts 1 kg butter 10 kg meat
Lutein	1.91	No RDA	50 g celery 100 g green peas 200 g asparagus 200 g green pepper 200 g yellow pepper
Selenium	0.032	50	100 g wheatmeal 150 g brown bread 500 g meat 1 kg vegetables
DHA	209	100	49 g sardine 165 g cod 170 g haddock 180 g carp

TERMS explained

Hyperlipidaemia A group of disorders characterised by an excess of fatty substances, such as cholesterol, triglycerides and lipoproteins, in the blood. The condition is an important risk factor in developing atherosclerosis and heart disease. Hyperlipidaemia can be caused by genetic factors or by secondary factors, including diet (high intake of saturated fat).

Prostaglandins A family of hormone-like chemicals produced in the body from the polyunsaturated fatty acid arachidonic acid and occurring naturally in all mammals. Prostaglandins are found in almost all tissues in the human body. They control many essential physiological functions including the regulation of blood clotting, smooth muscle contraction and inflammation.

Synergistic Having the capacity of discrete agents, for example drugs, such that the total effect is greater than the sum of the individual effects.

KEY points

- * Many people, both in Britain and worldwide, do not have balanced diets. Malnutrition is the result.
- * Eggs are widely eaten, used in cooking a variety of foods and easily obtained.
- * It is possible to enrich eggs in four nutrients which have important health-promoting properties.
- * Antioxidants are substances that protect the body against damage by free radicals.
- * Free radicals are produced naturally in the body and they are implicated in a variety of diseases.