Selenium-enriched eggs can improve the human diet

Animal nutrition can also benefit the human population, simply by enriching feed with the necessary nutrients. There is a real need in many countries to increase our selenium intake and with the controversy surrounding cholesterol in eggs at last reaching a conclusion, what better packaging is there for good human nutrition?

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After long heated debates about eggs, cholesterol and human health it seems likely that the storm has at last calmed and today we can say "An egg a day is OK!" and start thinking about egg improvement. The last 20-40 years have been associated with rapid progress in the poultry industry throughout the world. Indeed, between 1961 and 2002, world chicken egg output increased more than threefold, reaching 53.8 million tonnes and the output is predicted to grow further in the next 25-30 years. However, egg consumption in Europe and the USA was in decline for a period of 20 years. Only a few years ago it stabilised at about 12 kg/person/year and has even showed some growth for the last 2-3 years. Therefore there is a great opportunity for poultry producers in the future.

Unfortunately, egg production parameters were very seldom related to internal egg quality. In particular the chemical composition of eggs has never been an issue in relation to egg marketing. We assumed that it is the hen that is responsible for egg composition and because in nature the egg is laid to produce a chick, its composition should be optimal. Therefore, consumers' main concern when looking at labels was with the cholesterol level. A closer look at what in the egg is dependent on the laying hen and what can be manipulated via the diet shows that, from the nutritional point of view, proteins, lipids, vitamins and minerals represent major nutrients of interest. Of those nutrients, only the amino acid composition of egg albumin is quite resistant to dietary manipulation. In this respect egg albumin represents an ideal combination of essential amino acids and is a good protein source for the human diet. The total amounts of fat and cholesterol in the egg are also quite stable and difficult to change by dietary means. In stark contrast, the fatty acid profile of egg lipids and the vitamin and mineral content depend on their provision in the maternal diet.

Optimal egg composition

Ideally, an egg yolk should:-

- Contain a reasonable ratio of omega-3/omega-6 fatty acids (at least between 1:1 and 1:3);
- Have high concentrations of vitamin E and carotenoids;
- Be rich in such trace minerals such as selenium.

However, because commercial practice aims primarily to decrease egg production cost and the low requirement of laying hens in these nutrients, today's supermarket egg is far from the above criteria. In fact, the proportion of omega-6 fatty acids (the major fatty acids in most grains and seeds) is very high in egg yolk lipids and there are only traces of omega-3 fatty acids in eggs. This discrepancy in the fatty acid composition of commercial eggs in relation to human health is already addressed to a large extent by producing so called *designer* omega-3 enriched eggs. For example, in major UK supermarkets Columbus eggs (whse omega-3 : omega-6 ration is 1:1) can be easily found, including Columbus free-range eggs. It is interesting to note that our studies of eggs collected from various wild birds showed that they have similar ratio of omega-3: omega-6 fatty acids to the designer eggs. Therefore designing

Table 1 - Estimated selenium intake in the UK

Year	Se intake, mg/day	Reference
1974	60	BNF, 2001; Church, 2000
1978	60	Thorn *et al.,* 1978
1985	63	Church, 2000
1990	30	MacPherson *et al.,* 1993
1994	34	Barclay *et al.,* 1995
1995	29-39	BNF, 2001; Church, 2000
1997	29-51	BNF, 2001; Shortt *et al.,* 1997; MAFF,1997;1999
2000	39	Ysart *et al.*, 2000

Table 2 - Estimated intake of Se from various foods in the UK in 1997 (Adapted from BNF, 2001)

Food	% of total intake
Meat and meat products	32
Dairy products and eggs	22
Bread and cereals	22
Fish	13
Vegetables	6
Other foods	5

Designer quail's eggs are a niche market for the future.

Selenium-enriched eggs are already available in the supermarket.

Se-enriched eggs for the Ukraine.

Table 3 - Some characteristics of food choice for Se-enrichment (Adapted from Yaroshenko *et al.*, 2003)

THE FOOD SHOULD BE...	COMMENTS
A part of traditional meals for the population	- It would be counterproductive to attempt a change in culturally based food habits by introducing a new type of food. Emphasis should be given to the possibilities of changing the composition of existing foods, e.g. by selenium enrichment.
Consumed regularly in a moderate amount	- Since the objective is to deliver the amount of selenium needed to meet the RDA, it is necessary to choose foods that are consumed regularly in moderate amounts. Over-supplementation is unnecessary and undesirable.
Consumed by the majority of the population	- This is particularly important given that immune function is more likely to be compromised in groups such as children and the elderly.
Affordable	- Affordability of food plays an important role in the consumer choice.
Enriched with other health-promoting nutrients that are in short supply in the same population	- Examples of minerals critical to health that are frequently deficient include iron and iodine. Vitamin E and lutein are also in short supply in the human diet. This can give a greater improvement in the diet.
Supplying a meaningful amount of the nutrient (e.g. at least 50% RDA)	- his is an important point that distinguishes true functional foods from products that include 'tag-dressing' amounts of nutrients for advertising purposes.

omega-3 enriched eggs is nothing more than returning back to nature.

There is a range of other similar types of eggs available in supermarkets all over the world. Increased vitamin E concentration in the egg to deliver a daily requirement in this vitamin (15mg) is also a reality. Our study at the Scottish Agricultural College supported this and today such eggs (including Columbus in the UK) are on the market in various countries worldwide.

The production of Se-enriched eggs is the most recent development in the egg industry. This issue is especially important for European countries such as Scotland, where the daily requirement in Se is typically met by only 50% (*Table 1*). The problem with selenium consumption in European countries began when, in bread production, North American wheat, typically high in Se, was replaced by low Se European wheat, as a result of EU regulations. This reflects the high variability in the Se content of grains. In fact, the Se concentration in plant materials depends on its content in the soil, which varies greatly, but moreover, on the soil quality itself. For example, acid and low aerated soils are not good for Se absorption by plants. Furthermore, the use of artificial fertilisers rich in sulphur is also associated with decreased Se availability from soils.

The decline in selenium intake in the human diet is reflected in decreased serum and whole blood selenium concentrations. The low selenium concentration in the blood is associated with increased risk of spontaneous abortions in women and male subfertility, increased risk of cancer and increased cancer mortality rates. An inverse relationship between blood Se concentration and cardiovascular disease has also been reported. Epidemiological studies indicate an association between low dietary selenium status and increased risks of cardiomyopathy, cardiovascular disease and carcinogenesis in various sites of the body. Several studies have suggested that selenium deficiency may be associated with an increased risk of coronary heart disease. There are some indications that selenium can also regulate inflammatory mediators in asthma. Selenium supplementation of the human diet (200 µg daily for 4.5 years) was associated with a significant (by 50%) decrease in cancer mortality (Clark *et al.*, 1996). The selenium-treated group had substantial reductions in the incidence of prostate cancer, total cancer incidence and mortality. Selenium has also been shown to have other health-related benefits. Reilly (1998) listed more than 40 human diseases and conditions associated with selenium deficiency. These included aging, arthritis, cancer, cardiovascular disease, cataracts, cholestasis, cystyc fibrosis, diabetes, immunodeficiency, Kaschin-Beck disease, Keshan disease, lymphoblastic anaemia, macular degeneration, muscular dystrophy and stroke among others. Adequate selenium is also essential for immune function and can protect the immune system from oxidative damage.

Therefore, the low Se content of grains and other plant materials relates directly and indirectly to human health. A direct relationship is associated with a protective effect of Se against various diseases, including cancer and low Se consumption is associated with lower resistance to many other diseases. An indirect relationship between Se and human health is associated with low Se concentrations in animal-derived products as a result of low selenium content in their feeds. For example, the egg Se content can vary by several-fold depending on the chicken's dietary Se provision. Since the commonly used Se feed additives selenite or selenate are not effective in transferring Se to eggs, milk or meat, these products, when produced in Europe for example, are low in Se. It is interesting that in the UK the main contributors to daily Se consumption are meat and meat products (32%), dairy products and eggs (22%), bread and cereals (22%) and fish (13%, *Table 2*).

How can the poultry industry help?

Several important factors must be considered when choosing the best food supplementation strategy for a given population. Such factors are shown in *Table 3*. Among food animal products, the egg is ideally suited to meet these requirements. The egg is a traditional and affordable food in most countries and is consumed by people of all ages more or less regularly and in moderation. It is also a very safe vehicle for supplementation, given that a toxic dose of selenium from eggs would require consumption of 30 eggs per day over time, an unimaginable situation. There is also an option to simultaneously enrich eggs with

several important nutrients, including omega-3 fatty acids, vitamin E, carotenoids and with a single egg it is possible to deliver at least 50% of the RDA for selenium.

Our research work for the last 5 years has clearly shown that by using organic selenium in the form of selenised yeast (Sel-Plex, Alltech, USA) it is possible to substantially enrich eggs with selenium. In fact, the technology of selenium enrichment of eggs is very simple. By just replacing inorganic selenium with selenium yeast at level of 0.3 ppm it is possible to increase the Se concentration in the egg. Furthermore, inclusion of selenium yeast in the chicken's diet at 0.5-0.6 ppm provides eggs containing about 30 µg Se/egg- about 50% of the daily requirement for humans (55 µg in the USA and 60-75 µg in the UK; *Figure 1*). Our data also show that eggs enriched with Se have increased stability against lipid peroxidation during short storage.

The Se in eggs seems to be highly available. For example, a recent clinical trial conducted in the Ukraine showed that consumption of two Se-enriched eggs per day for eight weeks significantly increased the Se level of the plasma of volunteers. Furthermore, it is also possible to produce Se-enriched quail eggs that will fill a niche market for this product (*Figure 2*).

Se-enriched eggs are already on the supermarket shelves in different countries, including the Ukraine (*pictured*), Russia, Ireland, Malaysia, Thailand, Turkey, The Philippines, Switzerland and other countries. In the UK, Columbus eggs are also enriched with Se. The general trend is to deliver an egg with about 50% of the RDA for selenium. Furthermore, a combined enrichment of eggs with Se, vitamin E, carotenoids and omega-3 fatty acids is a viable option for future egg production. In fact, it has been proven that consumption of eggs enriched with lutein or vitamins is associated with increased concentration of these antioxidants in plasma of volunteers.

The advantages of enriching the egg yolk with antioxidants include:-

Decreased susceptibility to lipid peroxidation (enrichment of eggs with omega-3 PUFA is associated with increased susceptibility to peroxidation).

Prevention of fishy taste formation (the fishy taste is associated with the products of peroxidation of omega-3 fatty acids).

Designer eggs could be a good source of antioxidants in the human diet.

Further development of various types of designer eggs could be an important contribution to functional food development with a consequent improvement of the human diet. In relation to selenium, organic selenium can also be added to diets for pigs and broiler chickens to produce selenium-enriched meats, products that are already on the market in Korea. The recent results of Hintze *et al.* (2002) demonstrated that cattle fed diets high in Se from agricultural products can accumulate substantial amounts of Se in beef. Since cattle transfer dietary organic selenium to milk, selenium-enriched milk is also being considered for improvement of selenium status of children in some countries (Surai 2002). Therefore, it is possible to provide consumers with a range of animal-derived products with nutritionally modified composition in such a way that they can deliver substantial amounts of health-promoting nutrients to improve the general diet and help to maintain good health. Therefore, without changing the eating habits and traditions of various populations it is possible to solve problems related to deficiency of various nutrients, in particular selenium. The consumer will continue to go to the same supermarket to buy the same animal-derived products (eggs, milk and meat), cook and consume them as usual. The only difference will be in the amount of specific nutrients delivered with such products. ●

References are available from the authors on request.