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AN IMPORTANT SOURCE OF OMEGA-3 FATTY ACIDS, VITAMINS D AND E, CAROTENOIDS, IODINE AND SELENIUM: A NEW NATURAL MULTI-ENRICHED EGG

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Abstract: As natural eggs can contribute significantly to overcoming dietary deficits, we have designed and studied the composition of multiple-enriched eggs (Benefic® eggs) whose composition is close to the natural egg. They are obtained by feeding laying hens in the usual way, but using additional autoclaved linseed, minerals, vitamins and lutein to provide the extra components. These eggs have greater nutritional value than standard. Thus 100 g of these eggs contains 6 times more of the omega-3 fatty acid ALA (15% of the French recommended daily allowance (RDA)), 3 times more DHA (100% of RDA), 3 times more vitamin D (30% of RDA), 4 times more folic acid (70% of RDA), 6 times more vitamin E (66% of RDA), 6 times more lutein and zeaxanthine (70% of international recommendation), 2.5 times more iodine (100% RDA), and 4 times more selenium (45% RDA). As the content of omega-6 fatty acids remains unchanged, the omega-6/omega-3 ratio is lower, and thus improved. These eggs contain a little less cholesterol and, like standard eggs, are rich in vitamin B12 (160% of RDA) and vitamin A (25% of RDA), plus vitamin B2 (riboflavin), vitamin B5 (pantothenic acid) and phosphorus. Proteins quality is indeed excellent. These eggs are interesting for everybody, and particularly appropriate for older people. The nutritional value of enriched eggs (similar to the multiple-enriched eggs of this study) has been assessed in animals and in human volunteers in terms of their influence on blood lipids. They improve the blood concentration of omega-3 fatty acids, HDL cholesterol, LDL cholesterol and triglycerides.

Key words: Egg, omega-3 fatty acids, (n-3) fatty acids, ALA, DHA, lutein, zeaxanthin, iodine, selenium, vitamin D, vitamin B12, vitamin E, age related macular degeneration.

Introduction

Older people have particular nutritional requirements that are quite different from other groups. In fact, the nutritional status of many older people is poor in respect of some key nutrients, vitamins, minerals, omega-3 fatty acids and essential amino-acids. Moreover, older people are at higher risk of malnutrition if they are ill, live alone or have some difficulties in eating (1, 2) especially if being demented (3). Older patients should eat good and rich food, such as eggs, among others.

For years, until very recently, it was believed that the hen's metabolism ensured that the composition of eggs remained constant, regardless of the hen's diet. But recent studies on omega-3 fatty acids have raised fundamental questions about this dogma. Comparison of the compositions of "standard" eggs and those produced by Greek "free range" birds showed that the latter contained considerably more ALA (15 times) and DHA (6 times) (4). This is believed to be because the Greek hens eat purslane (a green plant), snails and slugs. It is thus possible to greatly increase the amounts of certain nutrients in eggs, making them more like "free range" eggs (this present stuy), or even further increasing these concentrations to produce "designer" eggs (5). In this latter case the hen is used as a biological concentrator. Feeding hens a diet based on linseed, as pioneered in countries such as the USA and Canada, increases the amounts of omega-3 fatty acids in eggs. This has now been tested in France (6). The objective of this study was to provide consumers with an inexpensive egg that was not just rich in omega-3 fatty acids, but one that also contained many vitamins and minerals. Several studies, including the French SU.VI.MAX (7) , have shown that the diet of a large segment of the population is inadequate. This has been taken most seriously by the French "Programe National Nutrition Santé" (PNNS) because of the associated risk of disease. In fact, it is clearly easy to improve the nutritional value of various (but not all) meats, meat products, fish and eggs, that to modify other dietary components, as reviewed recently (8).

Materials and Methods

Multi-enriched eggs (named Benefic® eggs produced by Glon, France) were produced by feeding laying hens in the usual fashion with a diet that included autoclaved linseed and complementary components. Batches of linseed mixed with wheat (type Socolin 60(r)) were autoclaved at high pressure and temperature so as to destroy all antinutritional factors in the linseed. This resulted in a diet enriched in plant lutein, vitamins E, D3, B9, iodine and selenium. The eggs were produced by a flock of 17,000 Isa Brown hens on a farm in northern Brittany during the month of February 2004. The birds were 32 weeks old when the sample of eggs was obtained. Samples of egg white and yolk obtained by mixing materials from 10 – 15 eggs

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were assayed (9 repeats) (9).

All assays were performed by a certified laboratory using standardized methods. Lipids were extracted (JORF 19.01.1988) and methylated according to the French standard NF EN ISO 5508 and the fatty acid profile obtained by gas chromatography on a Varian 3350 system equipped with a DB23 column, a FID detector and a temperature gradient of 80 - 200 °C. Experiments were defined according the by the French norm NF EN ISO 5509. The lipid contents are given as g/100g egg and the fatty acid profile as a percentage of total fatty acids.

Results and Discussion

The data for the major nutritional components are shown in Table 1. They show that multienriched eggs make a much larger contribution to the recommended daily allowance (RDA) than do standard eggs. These eggs contain 2.5 times more iodine per unit weight (providing 100% French RDA), 4 times more selenium (45% of French RDA), 3 times more vitamin D (30% of French RDA) 4 times more folic acid (70% of French RDA), 6 times more vitamin E (2/3 French RDA), 6 times more lutein and zeaxanthine (70% of International RDA), 6 times more omega-3 fatty acid ALA (15% of French RDA) and 3 times more of the other omega-3 fatty acid, DHA (100% of French RDA). The amounts of omega-6 fatty acids are the same as in standard eggs, so that the omega-6/omega-3 ratio is much better. Multienriched-eggs contain a little less cholesterol and, like all eggs, considerable amounts of vitamin A (25% of French RDA) and vitamin B12 (160% of French RDA), together with vitamins B2 (riboflavin) and B5 (pantothenic acid), plus phosphorus.

Omega-3 fatty acids

The first member of the omega-3 family of fatty acids is the essential fatty acid alpha-linolenic acid (ALA, 18:3(n-3)). The other omega-3 fatty acids are derived from ALA and have longer, more unsaturated aliphatic chains; the main derivatives are eicosapentaenoic acid (EPA, 20:5(n-3) and docosahexanoic acid (DHA, 22:6(n-3), cervonic acid). All the omega-3 fatty acids are important for treating or preventing cardiovascular disease, particularly obstructive ischemia (10, 11). They are also favorably implicated in other diseases, such as breast and colon cancers (12), prostate cancer (13, 14), inflammatory disorders (15) and perhaps even type II diabetes (16).

Omega-3 fatty acids are most important for the development of the brain (17), from the composition of cell membranes to cerebral function (18). They are even implicated in psychiatry (19). There is also evidence for the role of omega-3 fatty acids in aging; a lack of these fatty acids can alter lipid turnover in membranes. A balanced intake of omega-3 and omega-6 fatty acids that reflects the historical composition of the human diet can reduce the impact of several disorders or delay their onset (20). A paper on the evolution of the human brain has emphasized the importance of omega-3 fatty acids, which are abundant in the brain and are provided by dietary fish, seafood and eggs (21). It is generally assumed that people living in the Arctic are believed to derive most of their omega-3 fatty acids from fish and marine mammals; moreover, eggs are also an important source (22).

According to the RDA (23), diet is clearly deficient in ALA, in France (6, 24, 25) as in other countries. The estimated consumption of EPA and DHA in France indicates that adult persons in France consume twice the French RDA for DHA (25). But this varies considerably from one person to another. A

Table 1
Nutritional component of standard and multi-enriched eggs

per 100 g	Standard	multi-enriched eggs	improvement (multi-enriched / standard)	multi-enriched
% RDA				
Iodine (μg)	60	150	X 2.5	100
Vitamin D (μg)	0.5	1.5	X 3	30
Selenium (μg)	7	28	X 4	47
Folic acid (B9) (μg)	60	240	X 4	70
Vitamin E (μg)	1300	8000	X 6	66
Lutein + Zeaxanthine	250	1500	X 6	75 (recommended)
ALA (mg)	50			
(15 in USA)	300	X 6	15	
DHA (mg)	40			
(33 in USA)	120	X 3	100	
Vitamin A (μg)	175	180	X 1	23
Vitamin B12 (μg)	1,0	1.4	X 1.4	58

Table 2
Omega-3 fatty acids in French and USA standard eggs and Benefic® eggs

mg/100 g	Standard USA	Standard France (Glon)	multi-enriched	Greece	multi-enriched / Standard French
Cholesterol		440	400		-10%
Saturated fatty acids	2400	2800	2800	3000	
Monounsaturated fatty acids	3400	4200	3870	4280	
ALA (alpha-linolenic acid)	15	50	300	207	X 6
DHA	33	40	120	198	X 3
DPA	3			84	
Total omega-3 FA	51	100	430	531	X 4
LA (linolenic acid)	780	1400	1400	480	=
Total omega-6 FA	1017	1500	1500	693	=
Total PUFA		1580	1920		
omega-6/omega-3 ratio		15	3.5		-80 %

Standard USA and Greek eggs: (4) per 100g egg, adjusted to 30g yolk. DPA : docosapentaenoic, 22:5 omega-3. PUFA: poly-unsaturated fatty acids.

study on a small experimental sample in Brittany asked not to eat animal fats, including fish and sea products (6) found a consumption of less than half the RDA. An increased intake of ALA and DHA in easily obtained from multi-enriched eggs (Tables 2 and 3); as, indeed, the amount of omega-3 fatty acid in eggs depends in the hen's dietary intake (26).

Table 3
Fatty acids as % of total lipid

% total lipid	Standard	multi-enriched	Saturated
	14:0	0.3	0.2
	16:0	25.6	24.0
	18:0	6.6	8.3
Total saturated fatty acids		32.5	32.5
Monounsaturated			
I	16:1	4.1	3.1
	18:1	44.9	42.0
Total monounsaturated fatty acids	49.0	45.1	
Polyunsaturated			16.3
	ALA	0.6	3.5
	ARA	1.1	1.1
	DHA	0.5	1.5
Total PUFA		18.5	22.4
Total fatty acids		100	100
Long chain PUFA		2.2	6.1
Omega-6		17.4	17.4
Omega-3		1.1	5

ARA : arachidonic acid. Standard from Glon company, France

Animal studies have been done to evaluate the effects of omega-3 fatty acids supplied by enriched eggs on various lipid parameters and on the construction and function of biological membranes, particularly those of the brain (27). Phosphatidyl choline from eggs was found to influence learning by old rats (28).

In fact, the amount of ALA in the diet of laying hens was found to influence the composition of their eggs, which in turn influenced the physiology of the humans that consume the eggs (29): no significant changes in their plasma concentrations of total cholesterol, HDL cholesterol or triglycerides, but their circulating omega-3 fatty acids and DHA were significantly improved, with a decrease in the omega-6/omega-3 ratio in the phospholipids in the blood platelets of those who ate omega-3 fatty acid enriched eggs (30). Other studies gave similar results.

One experiment used "designer" eggs with measured contents of omega-3 fatty acids, selenium, lutein and vitamin E (5). The 44 volunteers (24 men, 20 women, average age 44 years) ate one "standard" or one "designer" egg per day for 8 weeks. Eating these eggs did not alter blood pressure, plasma total cholesterol or HDL-cholesterol, but it did result in increases, sometimes considerable, in certain nutrients and improved the fatty acid profiles of all classes of plasma lipids.

A diet including eggs enriched in omega-3 fatty acids improves the amounts of DHA in the red blood cells of older people (31).

Vitamins D and E (alpha-tocopherol)

Vitamin D is a major regulator of the formation and turnover of the bones, because of its influence on calcium (and phosphorus) metabolism (32). It also acts mainly to stimulate calcium absorption by the intestine, but it also regulates the

renal excretion of calcium. Humans obtain their vitamin D from two very different sources: the skin and the diet. Their relative contributions vary according to the climate and diet. In France, the vitamin D status of people varies with their exposure to sunlight (33), and that many French people lack vitamin D (almost 7/10), with women being more susceptible than men (34). Vitamin D-rich foods are rare. Salmon, herrings, halibut, oysters and eggs are all good sources of vitamin D, together with cod liver oil, but mammalian liver is not a good source, as being poorly consumed. Multi-enriched egg provide three times more vitamin D than do standard eggs, and thus provide about 30% of the RDA.

The main, but not the only, action of vitamin E is to block the formation of free peroxide radicals from oxygen and to trap any free radicals formed, particularly those formed from polyunsaturated fatty acids (35). Alpha-tocopherol is the only component of vitamin E used by brain cell membranes (the other tocopherols and tocotrienols are inactive) (36). The vitamin E in eggs (mainly alpha-tocopherol in multi-enriched eggs of the present study) does help to preserve the fatty acids in eggs kept at room temperature for 28 days (37). Moreover, the presence of extra amounts of both vitamin E and omega-3 fatty acids in eggs prolongs their shelf life by reducing oxidation (38).

Lutein and zeaxanthine

Lutein and zeaxanthine are not converted to vitamin A, they contributes to the colour of eggs, together with about twenty other carotenoids. They are almost always found in plants, with eggs being a major exception. While eggs contain less lutein and zeaxanthine than do vegetables, the caroteinoids in eggs are more bioavailable (39). Studies on volunteers (40) showed that lutein was better absorbed from eggs than from spinach (the richest dietary source), or from capsules (difference between amount swallowed and the plasma content) because the egg yolk lipid matrix, with cholesterol (200 mg/yolk), triglycerides (4 g/yolk) and phospholipids (1 g/yolk) plus lipid-soluble vitamins A, D and E increase the bioavailability of the carotenoids.

Lutein and zeaxanthine are important because they are concentrated in the macula of the retina, where they actively contribute to vision. They may thus help prevent age-related macular degeneration, which is believed to be the primary cause of blindness (41). Those patients with the highest concentrations of lutein and zeaxanthine in their blood are less prone of macular degeneration. Moreover, supplementing the diet with lutein increased the blood concentration together with its concentration in the macula of the eyes, the highest dietary concentrations of lutein and zeaxanthine were correlated with the lowest incidents of abnormal pigmentation (42). Consuming the enriched eggs ("designer" eggs) described above can double the plasma lutein concentration if the egg content is increased 15-fold, and cooking has no effect on their lutein content (5). A diet including eggs, broccoli and spinach will also help reduce the risk of cataracts (up to 20%) and age-related macular degeneration (up to 40%). A group of 8 epidemiological studies analysed the relationship between cataract and the amounts of lutein in the diet and blood plasma and 7 examined age-related macular degeneration (43).

Iodine and selenium

Iodine lack is the major preventable cause of brain disorders worldwide. A total of 740 million people suffer from goiter, and hence a lack of iodine (44). Epidemiological studies have shown that many people suffer from thyroid hypertrophy, which is worrying when it concerns women of child bearing age (45). A perfectly natural way of obtaining iodine is by eating naturally eggs enriched in this element. Multi-enriched eggs are a good source of iodine, together with mussels, oysters, fish, followed by standard eggs and Roquefort cheese.

Most of the biological functions of selenium are due to its incorporation into selenoproteins, where it is bound to the amino acid cysteine. The most important of these proteins are the enzymes glutathione peroxidase, the thioreductases and the deiodinases that catalyse the removal of iodine from thyroxine (T4) to give triiodothyronine (T3). The glutathione peroxidases provide a powerful defense against damage by free radicals, including within the brain (46). The activity of the enzyme that is specific for phospholipids is modulated by vitamin E (47). There is a direct link between a lack of dietary selenium and oxidative stress. Free radicals are believed to be the cause of several disorders, particularly cerebral aging. Selenium is also involved in the detoxification of xenobiotics and some heavy metals. A person's antioxidant status can be improved by consuming selenium-enriched eggs; this having the advantage of providing other antioxidants like vitamin E and the carotenoids. The selenium in eggs comes from the hens' diet and may be provided as a mineral or as an organic form (48). Multi-enriched eggs are an important source of selenium, along with certain fungi (cepes), mussels and calf's liver.

Cholesterol

It has long been held that the consumption of eggs should be restricted because of their cholesterol content. But a good part of human plasma cholesterol is of endogenous origin and the absorption of cholesterol by the gut of healthy humans is limited when the dietary input of cholesterol is high. Thus a moderate dietary intake of cholesterol is now considered to have only a moderate influence on plasma cholesterol (49). Moreover, in aged people, plasma cholesterol level is of low interest, and poorly in relation with the cardio-vascular risk.

A study in which subjects consumed 4 "designer" eggs per day for 4 weeks found no significant increase in total plasma cholesterol or LDL cholesterol, but a reduction in plasma triglycerides and reduced platelet aggregation. This suggests that omega-3 fatty acids cause the size of the LDL particles to change so that they become less atherogenic. Eating three of these "designer" eggs provides the same amount of omega-3

fatty acid as a portion of fish (50). And eating one "designer" egg does not alter plasma lipids or total cholesterol (5).

Conclusion

Eggs contain also other nutrients such as vitamin A B2 (riboflavin), B5 (pantothenic acid), B9 (folic acid) and B12 (cobalamin). Eating eggs also seems could help to face the reduced amount of ingested vitamin B12, due to reduced liver and meat consumption, particularly beef, and meat byproducts. The protein content of eggs is particularly well balanced. The nutritional requirements of older is an area of great interest because the extended life expectancy. Older adults are at greater risk for various nutritional deficiencies than are younger adults due to physiologic changes associated with aging, functional decline, acute and chronic illnesses, financial and social status. Among the important age-associated changes in nutrient requirements, the requirements for protein increase with age. Among the micronutrients, the significant ones that may be associated with deficiencies in elderly include vitamin B-12, vitamin A, C, D, calcium, iron, zinc, and most trace minerals (51). Indeed, micronutrients, as well as macronutrients, affect cognitive performances (17).

The dietary importance of a foodstuff depends not only on its constituents but also on their bioavailability. Undoubtedly some foods are much better dietary sources than others, and eggs are among the best. Finally, multi-enriched eggs (Benefic® eggs) are a low cost source of over 30% of the 10 most important essential dietary elements for humans: protein, vitamins E, D, B2, B9, B12, iodine, selenium, lutein and omega-3 fatty acids. Their composition is similar to that of free range eggs and, as such should rapidly become an essential reference for consumers.

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