Nutritional evaluation of egg components

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When carrying out a nutritional evaluation of eggs, the first point to mention is generally the high concentration of protein with a high biological value. Another positive aspect is the high content of several vitamins and minerals. Nevertheless, the amount of cholesterol in eggs and its contribution to the total human uptake of cholesterol is still a point of discussion among nutritionists.

On account of changed living conditions and progress in nutritional research, the demands on a modern diet have changed in recent decades. However, a balanced diet is still the basis of a healthy diet. What does 'balanced diet' mean: 'A balanced diet refers to the intake of appropriate types and adequate amounts of foods and drinks to supply nutrients and energy for the maintenance of body cells, tissues, and organs, and to support normal growth and development'. It simply means that a diet meets the nutritional needs adequately while not providing any macro or micronutrients in excess. To achieve a balanced diet, a variety of foods from *each of the food groups* of the food guide pyramid must be consumed. Eggs are found in one of these groups.

Today, however, that is not the full story. Knowledge of the relationship between the intake of specific nutrients and the incidence or the prevention of disease is opening new ways of specifically influencing interlinked physiological parameters.

For the purpose of nutritional evaluation egg components can be divided into three important groups:

1. components, which are found naturally in the egg in specific concentrations proteins, lipids, carbohydrates, vitamins, minerals, others
2. components, which are enriched in eggs through the hen feed e.g. vitamins, minerals
3. components, which are not found naturally in eggs and/or which are found only in very low concentrations but which are fortified through the hen feed or other new methods of manipulation e.g. phytoestrogens

Components, which are found naturally in the egg in specific concentrations

Until now the high content of highly bioavailable protein has provided a surplus. However, in most industrialized countries the supply of protein from eggs does not play an important role because of the high total protein intake. In addition, eggs are recognized as a major source of vitamins (A, E, B_2, B_6, B_{12}, folic acid) and minerals (iodine, iron, selenium, zinc) in the diet. The most important nutrients in eggs are listed in Table 1, in order to show the contribution of eggs to nutrient supply in terms of nutritional requirements.

Nevertheless, the amount of cholesterol in eggs and its contribution to the total human uptake of cholesterol is still a point of discussion among nutritionists. Recent reports have indicated that cholesterol from eggs does not have a negative effect on serum cholesterol levels (Weggemans *et al.* 2001, Hu *et al.* 2001). However, to increase popular acceptance the controversy surrounding the dietary cholesterol content of eggs and its effect must be revised (Herron and Fernandez 2004). However, for a food-based dietary recommendation the total amount of foods containing fat and cholesterol has to be considered (Wolfram 2001).

Table 1 Nutritional analysis of egg components.

Nutritional analysis of 1 egg (~ 60g, edible portion 53g)			
Constituent	**Amount per egg[1]**	**RDI or EDI[2]**	**% of RDI or EDI[2]**
Protein (g)	6.90	55	12.6%
Carbohydrates (g)	0.40	245	0.2%
Fat (g)	5.90	85	6.9%
Essent. fatty acids (g)	0.70	6.5	10.8%
ω-3 fatty acids (g)	0.20	1.6	12.5%
Vitamins			
Vit. A (mg)	0.14	1	14.0%
Vit. D (µg)	1.55	10[3]	15.5%[3]
Vit. E (mg)	1.10	13	8.5%
Vit. K (µg)	25.00	65	38.5%
Vit. B_1 (mg)	0.05	1.2	4.2%
Vit. B_2 (mg)	0.16	1.4	11.4%
Vit. B_6 (mg)	0.06	1.3	4.6%
Vit. B_{12} (µg)	1.06	3	35.3%
Folate (mg)	0.07	0.4[3]	17.5%[3]
Biotin (µg)	13.25	45	29.4%
Pantothenic acid (mg)	0.85	6	14.2%
Minerals			
Potassium (g)	0.08	3	2.6%
Calcium (mg)	30.00	800[3]	3.8%[3]
Phosphorus (mg)	115.00	700	16.4%
Magnesium (mg)	6.40	350	1.8%
Iron (mg)	1.10	15[3]	7.3%[3]
Zinc (mg)	0.72	8.5	8.4%
Iodine (mg)	0.01	0.15[3]	6.7%[3]
Fluoride (mg)	0.06	3.0	2.0%
Selenium (µg)	24.00[4]	45	53.3%
Others			
Cholesterol (mg)	210.00	300	70.0%

1 BLS (Bundeslebensmittelschlüssel - Federal foodstuffs database (Germany)) - version II.3 (1999)
2 RDI: Recommended Dietary Intake and EDI: Estimated Dietary Intake for adults (19 – 60 years) for Germany, Austria and Switzerland (D-A-CH 2000)
3 Reference nutrient intakes and goals for the adult population (EURODIET 2001)
4 Jeroch *et al.* 2002

Components, which are enriched in eggs through hen feed

Important egg components such as vitamins (and also functional plant components without vitamin activity), minerals or specific fatty acids can be enriched by composing hen feed in a specific way. Numerous publications have shown successful ways to manipulate the concentration of these substances in eggs, e.g. vitamin E (Flachowsky *et al.* 2000, Galobart *et al.* 2002, Jeroch *et al.* 2002), vitamin D (Mattila *et al.* 2003), folic acid (Sherwood *et al.* 1993, House *et al.* 2003), lutein (Surai 2002, Leeson 2004) or selenium (Jeroch *et al.* 2002, Yaroshenko *et al.* 2003) and iodine (Jeroch *et al.* 2002). It is well documented that the fatty acid composition and therefore the ratio of ω-3-/ω-6-fatty acids in egg yolk can be modified by altering the feed (Sim 2000).

From a nutritional point of view the amount of enriched nutrients in eggs should be high enough that beneficial effects can be detected and low enough that no adverse effects are expected. The desirable

amounts of nutrients in enriched eggs from a nutritional point of view are listed in Table 2. Some of this data has to be evaluated through practical feeding experiments.

Table 2 Suggestion for the nutrient content in enriched eggs.

Possible amounts of nutrients in 1 nutrient enriched egg (~ 60g, edible portion 53g)				
Constituent	**Amounts (on average) in enriched eggs**	**RDI or EDI[1]**	**% of RDI or EDI[1]**	**% of not enriched eggs[2]**
ω-3-fatty acids (g)	0.2 α-linolenic	2.0 α-linolenic	10%[3]	140%
(DHA + EPA)	+ 0.1(DHA + EPA)	+ 0.2 (DHA + EPA)[3]	50%[3]	172%
Vitamins				
Vit. D (µg)	1.55 (2.50[6])	10[3]	15(25[6])%[3]	100(161%[6])
Vit. E (mg)	3.50[4]	13	27%	318%
Vit. B12 (µg)	1.50	3	50%	142%
Folate (mg)	0.1	0.4[3]	25%[3]	135%
Minerals				
Zinc (mg)	2.00	8.5	23.5%	278%
Iodine (mg)	0.05[7]	0.15[3]	33%[3,7]	500%
Selenium (µg)	30.00	45	67%	125%
Others				
Lutein (mg)	4.00	8[5]	50%	-

1 RDI: Recommended Dietary Intake
EDI: Estimated Dietary Intake for adults (19 – 60 years) for Germany, Austria and Switzerland (D-A-CH 2000)
2 Referring to data from Table 1, column 2
3 Reference nutrient intakes and goals for the adult population (EURODIET 2001)
4 Meluzzi *et al.* (2000)
5 Leeson (2004)
6 only in countries with vitamin D deficiencies
7 only in countries with no iodine enriched salt

In addition to the amount of beneficial egg components present, bioavailability plays an important role in the supply of nutrients. Possible interactions between egg components during absorption and the nutritional state of the consuming individuals could (probably) affect the bioavailability. Most egg nutrients are highly bioavailable.

Studies with labelled egg protein enable true digestibility and assimilation to be determined. The results indicate a bioavailability of 65% for raw egg protein and 95% for cooked egg protein (Evenepoel *et al.* 1999). Bioavailability of preformed vitamin A is about 90%, but for vitamin active carotinoids the assimilation is lower depending on different factors (Castenmiller and West 1998, van het Hof et al 2000). New studies have suggested that vitamin D in eggs is almost exclusively 25-hydroxyvitamin D, which is absorbed better and faster and has greater biological activity than cholecalciferol (Ovesen *et al.* 2003).

The absorption rate of vitamin E differs widely between 15% and 65% and the reason for this is not well understood (Traber and Sies 1996). Lutein absorption is significantly higher from lutein-rich egg yolk than from vegetable or supplements (Handelman *et al.* 1999). A short overview of the bioavailability of nutrients (mostly from eggs) is presented in Table 3.

Table 3 Bioavailability of egg components.

Constituent	Bioavailability in humans
Protein	from eggs: raw ~ 65% - cooked ~ 95% (Enevepoel *et al.* 1998)
ω-3 FA	60 – 70% (Kinsella 1991)
Vitamins	
Vit. A	preformed > 95% (Borel *et al.* 2001)
carotinoids	mixed vegetable 10 –22%, green leafy vegetable 56 – 62% (van het Hof *et al.* 2000)
Vit. E	15 - 65% (Traber and Sies 1996)
Vit. B_2	~ 95% (FAO and WHO 2002)
Vit. B_6	51 - 91% (Roth-Maier *et al.* 2002, Gregory 1997)
Vit. B_{12}	in eggs: 24 - 36% (Doscherholmen et al 1975)
Folate	in egg yolk: ~ 70% (Seyoum and Selhub 1998)
Biotin	in raw eggs: low – in cooked eggs: high (Mock 1996)
Minerals	
Iron	Eggs in meals: ↓iron bioavailability (Hallberg and Hulthen 2000)
Zinc	Habitual diet: ~ 30% egg yolk powder: ~ 70% (O'Dell *et al.* 1972)
Iodine	high (Stanbury 1996)
Selenium	in eggs:78 – 82% (King 2001).
others	
Lutein	in egg yolk : high (Handelman et al 1999)

Recently tendencies towards a restriction of the nutrient enrichment of food have become clear, both in individual states and EU wide(BfR 2004a, 2005, Flynn *et al.* 2003). Consideration must be given to the risks of both undersupply and oversupply of nutrients because high doses of some nutrients can also cause adverse effects. For example, a published opinion from the FEEDAP Panel on the use of iodine in feedstuffs, which presents the worst case scenario model calculations with milk and eggs based on the current approved maximum iodine level in feed, shows that the Upper Limit of iodine for adults and adolescents could be exceeded. Reducing iodine to a maximum of 4 mg/kg in complete feed for dairy cows and laying hens would result in a satisfactory margin of safety for the consumption of milk and eggs (EFSA - FEEDAP 2005).

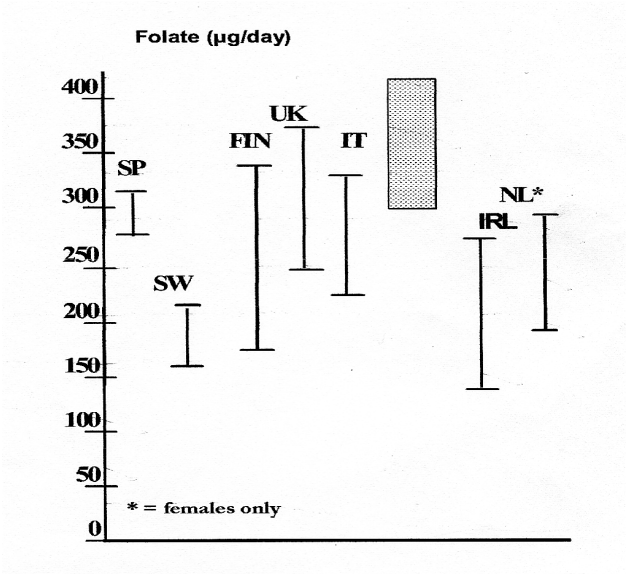
The opinions of the SCF (Scientific Committee on Food) on the Tolerable Upper Intake Level in humans of ß-carotene, vitamin A, B_1, B_2, B_6, B_{12}, D, E, K, folate, niacin, pantothenic acid, calcium, chromium, iodine, iron, magnesium, manganese, molybdenum, selenium and zinc provide the basis for the establishment of safety factors, where necessary, for individual vitamins and minerals, which would ensure the safety of fortified foods and food supplements containing these nutrients (SCF 2003). The Federal Institute for Risk Assessment (Germany) has published a proposal for the maximum levels of vitamins and minerals in fortified foods for Germany. This data is compared with the Tolerable Upper Intake Level published by the SCF in Table 4.

Table 4 Tolerable Upper Intake Level for vitamins and minerals per day (SCF 2003, SCF 2004) and proposed maximum levels in fortified foods (adapted from BfR 2004b, BfR 2004c).

Minerals	Tolerable Upper Intake Level / d[1]	Proposal for maximum levels in fortified foods[2]	Vitamins	Tolerable Upper Intake Level / d[1]	Proposal for maximum levels in fortified foods[3]
Calcium (mg)	2500	Only in milk product replacements	Vitamin A (µg)	3000[4] 800 – 2600[5]	No fortification (only margarine)
Chromium (µg)	n.d.	No fortification	Vitamin D (µg)	50[4] 25[5]	No fortification (only margarine)
Iodine (µg)	600[4] 200 – 500[5]	Only in salt	Vitamin E (mg)	300[4] 100 – 260[5]	15
Iron (mg)	n.d.	No fortification	Vitamin K (µg)	n.d.	80
Magnesium (mg)	250	15 – 28 mg/100 kcal	Vitamin B_1 (mg)	n.d.	1.3
Manganese (mg)	n.d.	No fortification	Vitamin B_2 (mg)	n.d.	1.5
Molybdenum (mg)	0,6[4] 0.1 – 0.5[5]	No fortification	Vitamin B_6 (mg)	25[4] 5 – 20[5]	1.2 – 1.6
Selenium (µg)	300[4] 60 – 250[5]	No fortification	Vitamin B_{12} (µg)	n.d.	3
Zinc (mg)	25[4] 7 – 22[5]	No fortification	Nicotinamide (mg)	150 – 700[5]	17
			Folic acid (µg)	1000[4] 200 - 800[5]	200
			Pantothenic acid (mg)	n.d.	6
			ß-Carotene (mg)	n.d.	No fortification

1 SCF 2003, iron: SCF 2004
2 BfR 2004c
3 BfR 2004b
4 = for adults
5 = for infants (differentiated in groups)
n.d. = assessed by SCF, an Upper Level however was not derived

In Europe the enrichment or fortification of food, especially eggs, should be concentrated on substances which are recognized as deficient or beneficial for the whole population or special groups of the population (e.g. pregnant women, elderly people, children) EU wide (EURODIET 2000a, BfR 2004d). One of the problems in this field is that the range of intakes and the range of EU member state recommendations for nutrients, e.g. for folate, differ considerably (Figure 1).



A = Austria,
B= Belgium,
FIN = Finland,
GER = Germany,
GR = Greece,
IRL = Ireland,
IT= Italy,
NL = Netherlands,
SP = Spain,
SW = Sweden,
UK = United Kingdom

Figure 1 Range of intakes (mean of highest to mean of lowest quartiles/tertiles) of folate (µg/d) in relation to range of member state recommendations (shaded boxes) for folate (from: EURODIET 2000b).

The report of the EURODIET project (EURODIET 2000a) suggests reference nutrient intakes (for some nutrients only) and goals for the adult population in the EU. For the evaluation of egg composition the recommendations on the content of folate from food, vitamin D, and iodine are the most interesting (Table 5).

Table 5 Reference nutrient intakes and goals for the adult population (from: EURO-DIET 2000a).

Component	Reference nutrient intakes and goals for the adult population
Folate from food (µg/d)	> 400
Vitamin D (µg/d) for elderly	10
Iodine (µg/d)	150 50 (infants) 200 (pregnancy)

The accepted problem nutrients of the EU should therefore receive the most emphasis. One of the next steps should be the assessment of the contribution of enriched eggs to the supply of such accepted functional substances (e.g. folic acid and vitamin D). Similar studies already exist on the contribution of folate fortification of foods e.g. flour, salt and milk to the supply of folate (Oakley 2002, Quinlivan *et al.* 2003, Burger *et al.* 2004).

Components, which are found only in very low concentrations in eggs

New trends in the research of functional substances in eggs are the transfer of phytoestrogens (e.g. isoflavones from soy beans; Lin *et al.* 2004) or conjugated linoleic acid (CLA) (Watkins et al 2003, Cherian *et al.* 2002) from the feed into the egg. The effects of these and various other functional substances are listed in Table 6.

Table 6 Examples of functional components and their health-enhancing effects.

Functional substances	Health-enhancing effects
ω-3 Fatty acids	Hypolipidaemic, antithrombotic and anti-inflammatory effect – may reduce the risk of atherosclerosis
CLA (conjugated linoleic acid)	May decrease risk of certain cancers
Folate	Decreases the risk of neural tube birth defects Reduces high homocysteine levels and may reduce the risk of atherosclerosis
Phytoestrogens	May reduce menopause symptoms, such as hot flashes May protect against some cancers and heart disease
Lutein	Contributes to maintenance of healthy vision (age-related macular degeneration)

For all the above-mentioned substances an essential step would be to conduct more clinical trials to prove the health benefits of the substances in unenriched and enriched eggs. In addition, the consumer must be educated about the beneficial effects to establish the credibility of the health claims.

An additional field of research is the isolation and purification of egg components with pharmaceutical effects, such as bioactive proteins e.g. lysozyme from egg white and immunoglobulin antibodies (IgY) from egg yolk with antibiotic activity (Kijowski *et al.* 2000, Coleman 2000).

Conclusions

Eggs are a good source of nutrients such as protein, vitamins (such as B_2, B_{12}, A, D, K and folic acid), minerals (such as selenium, iodine and iron) and functional substances like lutein, bioactive proteins and special fatty acids. Furthermore these components are highly bioavailable from eggs. With a moderate enrichment of nutrients according to the recommendations for fortification of foods, eggs could play an important role as a functional food. In addition to the nutritional value of the egg some egg components can be used as pharmaceuticals or food additives. However, the most important aspect for the promotion of eggs in the human diet should be the education of the consumer and the nutrition and health sector on the beneficial effects of natural egg components or substances that could be enriched in eggs.

References

BfR (Bundesinstitut für Risikobewertung – Federal Institute for Risk Assessment) (2004a): Dänemark verbietet bestimmte angereicherte Lebensmittel 27. Aug. 2004. http://www.bgvv.de/cm/208/daenemark_verbietet_bestimmte_angereicherte_lebensmittel.pdf,

BfR (Bundesinstitut für Risikobewertung – Federal Institute for Risk Assessment) (2004b): Verwendung von Vitaminen in Lebensmitteln – Toxikologische und ernährungsphysiologische Aspekte (in German) Berlin 03/2004. http://www.bgvv.de/cm/238/verwendung_von_vitaminen_in_lebensmitteln_bfr_wissenschaft_3_2004.pdf

BfR (Bundesinstitut für Risikobewertung – Federal Institute for Risk Assessment) (2004c): Verwendung von Mineralstoffen in Lebensmitteln – Toxikologische und ernährungsphysiologische Aspekte (in German) Berlin 04/2004 c, http://www.bgvv.de/cm/238/verwendung_von_mineralstoffen_in_lebensmitteln_bfr_wissenschaft_4_2004.pdf

BfR (Bundesinstitut für Risikobewertung – Federal Institute for Risk Assessment) (2004d):Common statement of representatives of national food safety agencies and institutions involved in nutrition in the European countries and Norway, 13. Jan. 2004 http://www.bgvv.de/cm/245/common_statement_of_representatives_of_national_food_safety_agencies_and_institutions_involved_in_nutrition_in_the_european_countries_and_norway.pdf

BfR (Bundesinstitut für Risikobewertung – Federal Institute for Risk Assessment) (2005): New assessment of risks and benefits of vitamins and minerals in food, 17 Jan. 2005 http://www.bgvv.de/cms5w/sixcms/detail.php/5962,

BLS (Bundeslebensmittelschlüssel – German Food Code and Nutrient Data Base) (1999): BLS Version II.3, BfR, Berlin

Borel,P., Pasquier, B.,Armand, M., Tyssandier, V., Grolier, P., Alexandre-Gouabau, M.C., Andre, M., Senft, M., Peyrot, J., Jaussan, V., Lairon, D. and Azais-Braesco, V. (2001): Processing of vitamin A and E in the human gastrointestinal tract. Am J Physiol Gastrointest Liver Physiol **280,** G95 – G103

Burger, M., Weißenborn, A., Klemm, C., Przyrembe,l H. and Mensink, G. (2004): Möglichkeiten zur Verbesserung der Folatversorgung – Eine Mehlanreicherung auch für Deutschland? Ernährungs-Umschau **51**, 8, 318 – 324

Castenmiller J.J.M. and West C. E. (1998): Bioavailability and bioconversion of carotenoids. Annu. Rev. Nutr. **18**,19-38

Cherian, G., Goeger, M.P.and Ahn D.U. (2002): Dietary conjugated linoleic acid with fish oil alters yolk n-3 and trans fatty acid content and volatile compounds in raw, cooked, and irradiated eggs**.** Poult Sci. **81**,**10**, 1571-1577

Coleman, M. (2000): Using egg antibodies to treat diseases. In: Egg Nutrition and Biotechnology. ed.: J.S. Sim, S. Nakai and W. Guenter, CAB International, pp. 351-370

D-A-CH (2000): Referenzwerte für die Nährstoffzufuhr [Reference values for nutrient intake], 1. Aufl., Umschau Verlag, Frankfurt

Doscherholmen, A., McMahon, I., Ripley, D. (1975): Vitamin B_{12} absorption from eggs. Proc Soc Exp Biol Med **149**, 987 - 990**.**

ESFA - FEEDAP (2005) (Panel on additives and products or substances used in animal feed): Opinion of the FEEDAP Panel on the use of iodine in feeding stuffs. http://www.efsa.eu.int/science/feedap/feedap_opinions/808_en.html

EURODIET (2000a): European Diet and Puplic Health: the continuing challenge, p. 23 http://eurodiet.med.uoc.gr/WP1/wp1_home.html

EURODIET (2000b), A Framework for food-based dietary guidelines in the EU p. 12 http://eurodiet.med.uoc.gr/WP2/wp2_home.html

EURODIET (2001): EURODIET Evidence, Public Health Nutrition, Vol 4, 2A + 2B

Evenepoel, P., Geypens, B., Luypaerts, A., Hiele, M., Ghoos, Y. and Rutgeerts, P. (1998): Digestibility of cooked and raw egg protein in humans as assessed by stable isotope techniques. J. Nutr. **128** (10), 1716 – 1722

FAO (1970): The Amino Acid Content of Foods and Biological Data on Proteins. Nutritional Study No 24., Rome

FAO and WHO (2002a): Human Vitamin and Mineral Requirements. Report of a joint FAO/WHO expert consultation. Chapter 3. Thiamin, riboflavin, niacin, vitamin B_6, pantothenic acid and biotin. Bangkok, Thailand http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/004/Y2809E/y2809e00.htm

FAO and WHO (2002b): Human Vitamin and Mineral Requirements. Report of a joint FAO/WHO expert consultation. Chapter 5. Vitamin $B_{12.}$ Bangkok, Thailand http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/004/Y2809E/y2809e00.htm

Flachowsky, G., Engelmann, D., Sünder, A., Halle, I. and Sallmann, H.P. (2000): Eggs and poultry meat as tocopherol sources in dependence on tocopherol supplementation of poultry diets. Proceedings of 5th Karlsruhe Nutrition Congress, Session 3P, p. 102

Flynn, A., Moreiras, O., Stehle, P., Fletcher R.J., Muller, D.J. and Rolland, V. (2003): Vitamins and minerals: a model for safe addition to foods. Eur J Nutr., **42**, 2, 118-30

Galobart, J., Barroeta, A.C. Cortinas, L., Baucells, M.D., Codony, R. (2002): Accumulation of alpha-tocopherol in eggs enriched with omega-3 and omega-6 polyunsaturated fatty acids. Poult Sci. **81**, **12**, 1873 – 1876

Gregory, J.F. III. (1997): Bio-availability of vitamin $B_{6.}$ Eur J Clin. Nutr. **51, 1**, 43 – 48

Hallberg, L. and Hulthen, L. (2000): Prediction of dietary iron absorption: an algorithm for calculating absorption and bioavailability of dietary iron. Am. J. Clinical Nutrition, **71, 5**, 1147 - 1160

Handelman, G.J., Nightingale, Z.D., Lichtenstein, A.H., Schaefer, E.J. and Blu, J.B. (1999): Lutein and zeaxanthin concentrations in plasma after dietary supplementation with egg yolk. Am J Clin Nutr. **70, (2**), 247-251

Jeroch, H., Eder, K., Schöne, F., Hirche, F., Böttcher, W., Sesekeviciene, J. and Kluge, H. (2002): Amounts of essential fatty acids, a-tocopherol, folic acid, selenium and iodine in designer eggs. International Symposium on Physiology of Livestock, Lithuanian Veterinary Academy, pp. 31-32.

Kijowsk,i J., Lesnierowski, G. and Fabisz-Kijowska, A. (2000): Lysozyme polymer formation and functionality of residuals after lysozyme extraction. In: Egg Nutrition and Biotechnology. ed.: J.S. Sim, S. Nakai and W. Guenter, CAB International, pp. 269 - 285

King, J.C. (2001): Effect of Reproduction on the Bioavailability of Calcium, Zinc and Selenium. Am. Soc. for Nutr. Sci., 1355S-1358S.

Kinsella, J.E. (1991): α-Linolenic acid: Functions and effects on linoleic acid metabolism and eicosanoid-mediated reactions. in : Advances in food and nutrition research, Vol 35, ed: Kinsella, J.E., Academic Press, London 1991, p 1-160 (p.21 and 22)

Leeson, S. (2004): Lutein enriched eggs: Transfer of lutein into eggs and health benefits. 3rd International symposium on egg nutrition for health promotion, p. 28,

Lin, F., Wu, J, Abdelnabi, M.A., Ottinger, M.A. and Giusti, M.M. (2004): Effects of dose and glycosylation on the transfer of genistein into the eggs of the Japanese quail (Coturnix japonica). J Agric Food Chem. **52, 8**, 2397-2403

Mattila, P., Rokka, T., Konko, K.. Valajy, J., Rossow, L.and Ryhanen, E.L. (2003): Effect of cholecalciferol-enriched hen feed on egg quality. J Agric Food Chem. **51, 1,** 281 – 287

Meluzzi, A., Sirri, F., Manfreda, G., Tallarico, N., and Franchini, A. (2000): Effects of Dietary Vitamin E on the Quality of Table Eggs Enriched with n-3 Long-Chain Fatty Acids. Poultry Sci. **79**, 539 – 545

Mock, D.M. (1996): Biotin. In: Luft F, Ekhard ZE, Filer LJ, eds. *Present Knowledge in Nutrition*. 7th edition. Washington, DC: ILSI Press; pp. 220-235

Oakley, G.P. (2002): Delaying folic acid fortification of flour. British Medical Journal **324**, 1348-1349

O'Dell, B.L., Burpo, C.E. and Savage, J.E (1978).: Evaluation of zinc bioavailability in foodstuffs of plant and animal origin. J Nutr **102**, 653 - 660

Ovesen, l., Brot, C. and Jakobsen, J. (2003): Food contents and biological activity of 25-hydroxyvitamin D: A vitamin D metabolite to be reckoned with? Ann Nutr Metab **47**, 107-113

Quinlivan, E. P. and Gregory, J.F.3rd (2003): Effect of fortification on folic acid intake in the united States. Am J Clin Nutr **77**, 221-225

Roth-Maier, D.A., Kettler, S.I. and Kirchgessner, M. (2002): Availability of vitamin B_6 from different food sources. Int J Fd Sci Nutr **53**, 171 - 179

SCF(Scientific Committee on Food) (2003):Tolerable upper intake levels for vitamins and minerals. http://www.europa.eu.int/comm/food/fs/sc/scf/out80_en.html,

SCF(Scientific Committee on Food) (2004): Opinion of the Scientific Panel on Dietetic Products, Nutrition and Allergies on a request from the Commission related to the Tolerable Upper Intake Level of Iron. 19 Oct. 2004 http://www.efsa.eu.int/science/nda/nda_opinions/690/nda_opinion19_ej125_tuiliron_en1.pdf

Sim, J.S. (2000): Designer egg concept: Perfecting egg through diet enrichment with ω-3 PUFA and cholesterol stability. In: Egg Nutrition and Biotechnology. ed.: J.S. Sim, S. Nakai and W. Guenter, CAB International, pp. 135 -150

Stanbury, J.B. 1996: Iodine deficiency and iodine deficiency disorders, present knowledge in nutrition Seventh Edition ILSI press, Washington D.C.

Surai, P. (2002): Diet as a main source of natural antioxidants in the human diet: A special place for designer eggs. SAC Annual Report 2002 - Research and Development Reports, pp. 50 –52

Traber, M.G. and Sies, H. (1996): Vitamin E in humans: demand and delivery. Annu Rev Nutr 16, 321-347

Van het Hof, K., West, C.E., Weststrate, J.A. and Hautvast, G.A.J. (2000): Dietary factors that affect the bioavailability of carotinoids. J Nutr **130,** 503–506

Watkins, B.A., Shulin-Feng, Strom, A.K., DeVitt, A.A., Liangli-Yu, Yong-Li (2003): Conjugated linoleic acids alter the fatty acid composition and physical properties of egg yolk and albumen. J Agric Food Chem **51**, 23, 6870-6876

Wolfram, G. (2001): Gibt es die "Entlastung für das Frühstücksei" wirklich? [Has there really been an exoneration of the breakfast egg? [in German] Internist **42**, 758 – 759

Yaroshenko, F.O., Dvorska, J.E., Surai,. P.F. and Sparks, N.H.C. (2003): Selenium-enriched eggs as a source of selenium for human consumption. Applied Biotechnology – Food Science and Policy **1**, 13 – 23