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Effect of housing systems on biochemical composition of chicken eggs

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Abstract. The aim of this study was to investigate the impact of production system (organic, conventional) on the quality of chicken eggs. Energetic value, carbohydrate, cholesterol, protein, fatty acid, sodium, potassium, phosphorus, dry matter and vitamin contents were evaluated. The mean content of cholesterol was 30%, and potassium 7%, greater in the organic eggs compared with the conventional eggs. No significant difference was found in the content of fatty acids, protein, sodium or dry matter. The organic eggs had considerably lower contents of calcium (2.8 times) compared with eggs from conventional farming. Negligible differences were found in the occurrence of vitamins (vitamin A, vitamin E, vitamin D3). The residues of 45 pesticides and 6 PCB isomers were analyzed in both types of eggs and no residues compounds were found.

Key words: chicken egg, biochemical composition, farming system, organic egg, conventional egg, egg quality, cage, calcium; cholesterol, egg protein, vitamins, potassium, energetic value, fatty acids, carbohydrates, sodium, phosphorous, dry matter

INTRODUCTION

Eggs play an important role in our everyday food. In 2007 total egg production in the world was ca. 62.6 million tons, the European Union produced 9.9 million tons, representing 170 billion eggs (FAO, 2009).

Chicken eggs are one of the most versatile foods. They contain high-quality proteins, carbohydrates, easily digestible fats and minerals, as well as valuable vitamins (Huopalahti, 2007). Due to their multifunctional properties (e.g., foaming, gelling and emulsifying), eggs are also widely used in the food industry and they are very good potential sources of raw materials for the pharmaceutical and cosmetic industries. In recent years several different methods andsystems for producing eggs have evolved. These systems vary in how the birds are housed, fed and managed. Layer nutrition and husbandry system significantly influences the sensory characteristics and the chemical composition of eggs (Ternes & Leitsch, 1997).

Recently, egg quality has been highlighted because of raised awareness of consumers. Several studies have been carried out to investigate and compare egg quality traits of laying hens reared in organic and conventional systems (i.e. egg, albumen, yolk, shell weight, albumen height eggshell breaking strength and thickness, yolk colour, whipping capacity etc.). Results of a study by Minelli et al. (2007) showed that eggs, as well as their components, were lighter and eggshell breaking strength lower in the organic system. Contrarily Hidalgo et al. (2007) reported that organic eggs were heavier and had better breaking strength than conventional ones. Higher values of yolk colour were observed in eggs from conventional systems (Hidalgo et al., 2007; Minelli et al., 2007).

Heretofore, few studies have been made in order to evaluate the chemical composition of chicken eggs. The aim of this study was to analyse the impact of housing system (organic vs conventional) on the quality parameters of chicken eggs.

MATERIALS AND METHODS

Eggs and hens. Two samples of freshly-laid eggs (size M) from organic and conventional farming systems were collected in January 2009. At laying time the organic hens were 246 and the conventional hens 257 days old. The hens' genotype in both rearing systems were Hy-Line Brown. The organic chicken eggs were purchased from a certified organic poultry fancier. The birds had been raised by certified organic production methods from hatching. The layers had outdoor access all the year round. Fodder was certified organic, its constituents were cereal, hay, clover, vegetables and green crop, according to the season of year. The hens ate *ad libitum* and feed was always available. No antibiotics or production stimulants were used. Conventional eggs were brought from a commercial poultry farm. Layers were kept in cages where the area for each hen was maximally 1,000 cm^2 and height was 40 cm. The layers ate 110–115 g balanced biocomplete cereal-based mixed fodder with several additives daily. Instead of adding antibiotics and production stimulants into feed, prophylactic vaccinations were used. In agreement with the producers the name of the companies has not been publicized here.

Analyses. Chemical analyses were carried out in two accredited laboratories: the Laboratory of Health Protection Inspectorate in Tartu and the Estonian Veterinary and Food Laboratory. Each sample consisted of 20 eggs. In the laboratory, the eggs were kept at 4°C and analysed not later than four days after laying.

Energetic value, carbohydrate, cholesterol, protein, fatty acids sodium, potassium, phosphorus, calcium, ash, dry matter, yolk and vitamins (A, E, D) contents were assessed. Retinol, cholecalciferol, α-, β-, γ- and δ-tocopherol contents were determined by high performance liquid chromatography (HPLC) (Table 1). Cholesterol and fatty acid Contents were assessed by gas chromatography (Table 2). Sodium and potassium concentrations were measured by atomic absorption spectroscopy (5K-TJ-66 AAS flame). The fat content was determined using the Schmid-Bondzynski-Ratslaff (SBR) method according to the accepted standard (Nordic 1989). For calcium valuation a flow injection analysis (FIA) spectrofluorometric method, and for the nitrogen content the Kjeldahl method ISO 937:1978 were used. Energetic value and carbohydrate contents s were determined computationally. Carbohydrates were calculated using the following formula; 100% - (protein% + fat% + humidity% + ash%). Dry matter was assessed by removing water at 102°C, phosphorus content by the spectrophotometric method, ash content by incineration in a furnace at 550°C.

The residues of 45 pesticides and six PCB isomers were analyzed in both types of eggs by the gas chromatography-mass spectrometry method (GC/MC).

Statistical analyses were carried out using the program Statistica 8.0 (StatSoft Inc. USA). Comparisons of vitamin contents in conventional and organic eggs were analysed using the t-test. Mean values of nutritional parameters were compared in different housing systems and standard errors of means were calculated.

RESULTS AND DISCUSSION

The nutritional content of the organic and conventional farmed eggs showed some differences. The vitamincontent of egg yolk showed significant differences between housing systems (Table 1). The mean percentage of yolk was greater in conventional than in organic eggs (respectively: 30.3% and 27.4%). Compared with organic, the concentration of retinol (vitamin A) was higher in conventional egg yolk (t = 10.04; df = 6; P < 0.00006). The contents of α-tocopherol, γ-tocopherol and vitamin D_3 in the yolk were significantly greater in conventional than in organic eggs (Table 1). A significantly higher level of β-tocopherol was found in the organic system eggs. No differences between farming systems were found in the content of δ-tocopherol.

Table 1. The mean content (±SE) of vitamins and differences between housing systems (N=4) in egg yolk (mg 100 g^{-1}).

Variable	Results		t	P	Method
	Conventional	Organic			
Retinol (vitamin A)	0.57 (±0.004)	0.46 (±0.01)	10.04	< 0.00006	T34-HPLC
α-tocopherol	14.90 (±0.24)	6.20 (±0.03)	35.87	< 0.00001	T35-HPLC
β-tocopherol	0.25 (±0.02)	0.36 (±0.01)	-5.21	< 0.002	T35-HPLC
γ-tocopherol	0.62 (±0.05)	0.22 (±0.01)	8.28	0.0002	T35-HPLC
δ-tocopherol	<0.05	<0.05			T35-HPLC
Cholecalciferol (vitamin D3)	0.014 (±0.001)	0.008 (±0.001)	6.60	0.0006	T41-HPLC

Results are presented with expanded uncertainty U (k=2).

The concentration of vitamins is influenced by genetics, rate of egg production and, as is the case with fatty acids, it varies with the composition of the hen's diet (Naber, 1993; Leeson & Caston, 2003). As the concentration of fat-soluble vitamins in the feed increases, so does the content of vitamins in the egg yolk (Sirri & Barroeta, 2007). Numerous publications have shown successful ways of manipulating the concentration of these substances in eggs, e.g. of vitamin E (Flachowsky et al., 2000; Galobart et al., 2002; Jeroch et al., 2002) and of vitamin D (Mattila et al., 2003). Egg yolk is one of the few foods that naturally contain vitamin D (Holick, 2002). According to several studies by Mattila et al. (1999, 2003, 2004) the cholecalciferol content of eggs is proportional to the level of added cholecalciferol in hen feed. However, for some vitamins, such as vitamin A, the liver acts as a reservoir so that the concentration in the yolk is buffered against large changes in the diet (Naber, 1979).

A difference between organic and conventional eggs was also found in the contents of cholesterol and calcium (Table 2).

Table 2. The mean values (± SE) of several egg quality parameters in different housing systems.

Parameters	Results		unit	Method
	Conventional	Organic		
Computational Energetic value	133 557	127 530	kcal 100 g^{-1} kJ 100 g^{-1}	5K-TJ-87
Computational carbohydrates **	1.0±0.1	1.9±0.25	%	5K-TJ-89
Total nitrate (protein) **	12.35±0.49	11.9±0.48	%	ISO 937:1978
Cholesterol	341	489	mg 100 g^{-1}	5K-TJ-91 GC*
Fatty acids ** 1)saturated FA 2)monounsaturated FA 3)polyunsaturated FA a)omega-3 FA b)omega-6 FA c)trans FA	 2.5±0,2 3.2±0.3 1.6±0.2 0.2±0.2 1.4±0.2 0.1±0.01	 2.3±0.1 3.2±0.3 1.1±0.1 0.1±0.01 1.0±0.1 0.1±0.01	% in product	5K-TJ-60 GC
Potassium **	122±25	131±27	mg 100 g^{-1}	5K-TJ-66 AAS flame
Sodium **	134±20	131±20	mg 100 g^{-1}	5K-TJ-66 AAS flame
Total phosphorus	173	164	mg 100 g^{-1} P	5K-TJ-6*
Dry matter **	23.15±0.23	22.6±0.23	%	5K-TJ-2
Fat **	8.88±0.44	7.94±0.4	%	5K-TJ-5 SBR
Calcium	38.2	13.6	mg 100 g^{-1} Ca	5K-TJ-40 FIA*
Ash **	0.91±0.03	0.89±0.03	%	5K-TJ-29

* Method is not accredited

** Results of analysis with expanded uncertainty U (k=2)

The organic eggs had considerably lower contents of calcium (2.8 times; 13.6 vs 38.2 mg 100 g^{-1} Ca) compared with eggs from conventional farming. The concentrations of cholesterol and potassium were 30% and 7% greater in the organic eggs compared with the conventional. These results are in accordance with the findings of Minelli et al. (2007).

The cholesterol content of eggs has become a very important quality criterion for the consumer. Cholesterol has an important role in the development of the embryo, it is a structural component of cell membranes and is a precursor for hormones, vitamin D, and bile acids (Anton, 2007). The cholesterol concentration in eggs depends on the breed and age of layers, on management and on nutrition (Föster & Flock, 1997) and partly on synthesis in the liver during the synthesis of lipoproteins. Vilà (2008) found that cholesterol content was positively correlated with egg and yolk weight, and negatively correlated with egg production and dietary protein level. However, these correlations were not significant when cholesterol concentration was expressed as milligrams per gram of yolk.

Our study showed that the concentration of carbohydrates was higher in organic eggs, but the energetic value was greater in conventional eggs (Table 2). Also, conventional eggs contained more phosphorus, dry matter, protein and fat. Contrary findings have been reported by Italian researchers (Minelli et al., 2007), who reported more protein and dry matter in organic eggs.

No significant differences were observed in fatty acid, sodium and ash levels. Essential fatty acid content in eggs is not genetically encoded, but rather reflects the hen's dietary fatty acid. About 20% of total fat is comprised of essential fatty acids, of which 90% are n-6 PUFA and 10% n-3 PUFA. However, this ratio depends on the composition of the feed (Seuss-Baum, 2007). No residues of compounds of 45 pesticides and six PCB isomers were found in either farming system.

CONCLUSION

Our pilot study showed that differences in eggs chemical composition between organically and conventionally reared hen eggs was significant. Differences were found in the content of vitamins, cholesterol, calcium and potassium. Several studies have found that egg content significantly depends on layers nutrition. Also, fodder ingredients are a very important reason why the chemical composition of eggs may vary. Therefore, because the organic and conventional farming systems are grounded on different feeding systems, it can be concluded that chemical composition of hen eggs might be affected by housing system. More detailed and comprehensive studies are needed to establish the impact of housing systems on egg quality as well as chemical composition.

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