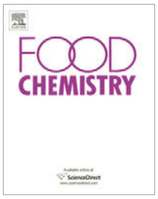
Food Chemistry 116 (2009) 911–914

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem



Fatty acid composition of certified organic, conventional and omega-3 eggs

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ARTICLE INFO

Article history:
Received 1 July 2008
Received in revised form 9 March 2009
Accepted 12 March 2009

Keywords:
Fatty acids
Egg
Organic
Conventional
Omega-3

ABSTRACT

The objective of this study was to compare the fatty acid composition of commercially available conventional, certified organic, and omega-3 eggs. Egg components were assessed, and the fatty acid composition of yolk lipids was determined by gas chromatography. Organic egg yolk contained a higher percentage of palmitic and stearic acids than did conventional yolk ($P < 0.05$) with no differences observed in the monounsaturated or polyunsaturated fatty acid compositions. Compared with organic and conventional eggs, omega-3 egg yolk contained lower percentages of myristic and palmitic acids, and higher omega-3 fatty acids. In a sub-analysis of conventional egg types, the percent of stearic acid in "cage" egg yolk was significantly lower ($P < 0.05$) than those of "barn-laid" and "free-range" eggs. "Cage" eggs had a significantly lower percentage ($P < 0.05$) of arachidonic acid than had "barn-laid" eggs. Consumption of omega-3 eggs has the potential to confer health benefits through the increase in intake of omega-3 fatty acids. With regard to organic or conventional methods of production, the small differences in saturated fatty acids observed in the present study are unlikely to have any significant metabolic effect on the consumer.

1. Introduction

The Food and Agricultural Organisation of the United Nations (FAO, 1999) defines "organic" as a process whereby natural inputs are approved and synthetic inputs are prohibited. Organic agricultural practices aim to enhance biodiversity, biological cycles and soil biological activity so as to achieve optimal natural systems that are socially, ecologically and economically sustainable.

Organic production systems are growing in popularity, with an estimated 31 million hectares in 120 countries dedicated to organic farming (Yussefi, 2006). Consumers judge organic products positively and associate them with health (Zanoli & Naspetti, 2002; Zhao, Chambers, Matta, Loughin, & Carey, 2007) and environmental benefits (Shepherd, Magnusson, & Sjödén, 2005; Zhao, Chambers, Matta, Loughin, & Carey, 2007). Although evidence available regarding the environmental impact of different agricultural methods is still in its infancy, it has been estimated that organic systems utilise less energy-intensive methods than do conventional practices, and therefore contribute a smaller share of greenhouse gases and have greater potential for carbon sequestration (Ziesemer, 2007).

Whilst few and inconsistent differences in the nutrient composition of organically and conventionally produced foods are demonstrated in the literature, there are trends showing that organic foods of plant origin have a lower nitrate content and a higher vitamin C content than have their conventional counterparts (Williams, 2002; Worthington, 2001).

A small number of studies have involved the effect of agricultural methods on the fatty acid composition of foods from animal sources. Limited data suggest that the fatty acid compositions of lamb (Nürnberg et al., 2006) and beef (Walshe, Sheehan, Delahunty, Morrissey, & Kerry, 1996) are unaffected by the method of production; and organic chicken has less alpha-linolenic acid (ALA) and more linoleic acid (LA) than has conventionally produced chicken (Jahan, Paterson, & Spickett, 2004). Milk produced through organic practices has been shown to have higher amounts of polyunsatured fats (Bergamo, Fedele, Iannibelli, & Marzillo, 2003; Ellis et al., 2006; Fievez & Vlaeminck, 2006; Jahreis, Fritsche, & Steinhart, 1996) and a lower ώ-6 : ώ-3 fatty acid ratio than has conventional milk (Ellis et al., 2006; Wong, Ahmad, Phuyal, & Samman, 2006), whilst other studies report no clear effect on milk fatty acid composition (Ellis et al., 2006; Toledo, Andrén, & Björck, 2002).

Organic eggs are reported to have similar (Cherian, Holsonbake, & Goeger, 2002) or higher (Hidalgo, Rossi, Clerici, & Ratti, 2008) levels of saturated fat as compared with eggs from other production systems. In view of the contentious nature of egg lipid composition and its relationship to heart disease, this study was undertaken to compare the egg components and yolk fatty acid composition of commercially available conventional, certified organic and omega-3 eggs.

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doi:10.1016/j.foodchem.2009.03.046

2. Materials and methods

2.1. Sample collection and preparation

A total of 180 eggs [conventional ($n = 96$), organic ($n = 72$) and omega-3 ($n = 12$)] were purchased from supermarkets and organic food outlets in the Sydney metropolitan area. Certified organic eggs were identified, based on the presence of an organic logo, and conventional eggs included "cage", "free-range" and "barn-laid" eggs. The weight of each egg and eggshell was recorded. The yolks were isolated and weighed, and the albumen weights were calculated by difference.

2.2. Lipid extraction and fatty acid analysis

Two egg yolks from each type of egg were combined to form a single sample. The egg yolks were homogenised and total lipid was extracted (Folch, Lees, & Sloane-Stanley, 1957) and determined gravimetrically after the evaporation of solvent. Fatty acid methyl esters (FAME) were prepared by direct transesterification (Lepage & Roy, 1986) and analysed by gas chromatography (Agilent 6850 Series GC System, Agilent Technologies, Santa Clara, CA, USA) with flame ionisation detection as reported previously (Samman et al., 2008). FAME were analysed using a fused carbon–silica capillary column (phase: cyanopropylphenol/dimethyl polysiloxane, 0.25 µm; column: 30 m × 0.25 mm; type: DB-225, J & W Scientific, Agilent Technologies, Santa Clara, CA, USA). The flow rate of the hydrogen carrier gas was 1.0 ml/min, at a pressure of 500 kPa. The injector port and detector temperature were maintained at 300 °C. The column oven was programmed to maintain a temperature of 170 °C for 2 min, then rise to 190 °C at 10 °C/min and maintain that temperature for 1 min, before rising to a plateau of 220 °C at a rate of 5 °C/min. The total run time per cycle was 25 min. Peak areas and retention times were calculated (Agilent ChemStation Software, Rev. B.03.01 (317), Agilent Technologies, Santa Clara, CA, USA) and FAME were identified by comparing retention times to a standard mixture, with added eicosapentenoic acid (GLC 68C, Nu-Check Prep, Elysian, MN).

2.3. Statistical analysis

One-way analyses of variance were carried out with type of egg as the fixed factor (i.e. conventional, organic, omega-3). *Post hoc* comparisons were carried out using the least significant difference method, without any adjustment for multiple comparisons, and $P < 0.05$ was taken to indicate statistical significance. All formal analyses were carried out using SPSS (version 14; SPSS INC., Chicago, IL, USA).

3. Results

In total, 180 eggs were available for analysis in the present study. Significant variation between egg types was observed in the physical egg components (Table 1). The total weights of omega-3 eggs were significantly lower than were conventional and organic eggs, with conventional eggs being the heaviest. Similar trends were observed for egg yolk and albumen weights, but when expressed as a percentage of total egg weight these differences were no longer significant between the various egg types. The eggshell weight, expressed as a percentage of total egg weight, was highest in omega-3 eggs and lowest in organic eggs ($P < 0.05$). The edible portion weight was similar between the three groups;

Table 1
Components of conventional, organic and omega-3-enriched eggs[1].

Egg components	Conventional eggs ($n = 96$)	Organic eggs ($n = 72$)	Omega-3 eggs ($n = 12$)
Egg weight (g)	61.70 ± 3.70^a	59.62 ± 4.17^a	54.92 ± 1.42^a
Yolk (g)	16.10 ± 1.80^a	15.87 ± 1.95^b	14.64 ± 1.15^{a,b}
Yolk (percentage of egg weight)	26.07 ± 2.30	26.56 ± 2.15	26.66 ± 1.81
Albumen (g)	38.3 ± 3.58^a	37.3 ± 2.61^a	33.5 ± 0.99^a
Albumen (percentage of egg weight)	62.1 ± 4.70	62.6 ± 2.67	61.1 ± 1.51
Shell (g)	7.01 ± 0.60^a	6.57 ± 0.60^a	6.75 ± 0.34
Shell (percentage of egg weight)	11.37 ± 0.74^a	11.03 ± 0.79^a	12.29 ± 0.49^a
Edible portion (g/100 g)	88.19 ± 4.39	89.16 ± 1.95	87.71 ± 0.49
Yolk fat (g/100 g) [2]	4.43 ± 0.55^a	4.45 ± 0.71^b	4.03 ± 0.41^{ab}

$^{a–c}$Values sharing a common superscript within a row are significantly different ($P < 0.05$).

[1] Data shown as means ± SD.

[2] Yolk fat data shown as means of paired conventional ($n = 48$), organic ($n = 36$) and omega-3 ($n = 6$) samples.

Table 2
Fatty acid composition of conventional, organic and omega-3-enriched egg yolks[1].

Fatty acid (percentage of total)	Conventional eggs ($n = 48$)	Organic eggs ($n = 36$)	Omega-3 eggs ($n = 6$)
C14:0	0.36 ± 0.06^a	0.35 ± 0.04^b	0.26 ± 0.03^{a,b}
C16:0	25.1 ± 1.07^c	25.5 ± 0.94^c	22.7 ± 0.70^c
C16:1 (n-7)	3.23 ± 0.61	3.03 ± 0.77	2.79 ± 0.27
C18:0	8.37 ± 0.59^a	8.77 ± 0.69^a	8.28 ± 0.74
C18:1 (n-9)	46.7 ± 3.02	46.0 ± 3.19	44.6 ± 0.36
C18:2 (n-6)	13.1 ± 3.14	13.1 ± 2.24	13.7 ± 0.64
C18:3 (n-3)	0.51 ± 0.20^a	0.50 ± 0.15^b	4.52 ± 0.22^{a,b}
C20:4 (n-6)	1.83 ± 0.16^a	1.88 ± 0.14^b	1.12 ± 0.10^{a,b}
C22:6 (n-3)	0.85 ± 0.16^a	0.84 ± 0.17^b	2.05 ± 0.28^{a,b}
Total saturated	33.8 ± 1.20^a	34.6 ± 1.10^a	31.3 ± 0.65^a
Total monounsaturated	50.0 ± 3.35	49.0 ± 3.12	47.4 ± 0.43
Total polyunsaturated	16.3 ± 3.50^a	16.4 ± 2.56^b	21.4 ± 1.04^{a,b}
Total n-6	15.0 ± 3.23	15.0 ± 2.30	14.8 ± 0.74
Total n-3	1.36 ± 0.33^a	1.34 ± 0.30^b	6.57 ± 0.34^{a,b}
n-3:n-6	0.09 ± 0.01^a	0.09 ± 0.01^b	0.44 ± 0.01^{a,b}

$^{a–c}$Values sharing a common superscript within a row are significantly different ($P < 0.05$).

[1] Data shown as mean ± SD.

however, total yolk fat was significantly lower in the omega-3 eggs ($P < 0.05$) than in the organic and conventional eggs (Table 1).

Significant differences were observed in the fatty acid compositions of organic, conventional and omega-3 eggs (Table 2). Organic yolk fat contained higher percentages of palmitic (C16:0) and stearic (C18:0) acids than did conventional yolk ($P < 0.05$), which was reflected in an overall higher percentage of saturated fats in organic eggs ($P < 0.05$). No differences were observed in the monounsaturated or polyunsaturated fatty acid composition of organic and conventional eggs. Yolks from omega-3-enriched eggs were significantly lower in myristic (C14:0) and palmitic acids than were organic and conventional eggs, resulting in a significantly lower total saturated fatty acids content (Table 2). Significantly higher levels of ALA (C18:3, $P < 0.05$) and docosahexaenoic acid (DHA, C22:6, $P < 0.05$), in omega-3 eggs contributed to a higher omega-3 fats content and n-3:n-6 ratio than in organic and conventional eggs.

A sub-analysis was undertaken to compare the physical components and fatty acid composition of eggs produced by different conventional methods, namely "free-range", "barn-laid", and "cage" eggs. Egg components were similar to those observed for conventional eggs (data not shown). The yolk fat percentage in "cage" eggs (4.11 ± 0.54, mean ± SD, $n = 12$) was significantly lower ($P < 0.05$) than the fat percentages of "barn-laid" (4.47 ± 0.59, $n = 12$) and "free-range" eggs (4.46 ± 0.49, $n = 18$). The percent of total saturated fatty acids in "cage" eggs (33.0 ± 1.16) was significantly lower ($P < 0.05$) than in "barn-laid" (34.1 ± 0.57) and "free-range" (34.1 ± 1.41) eggs, mainly due to a significantly lower percentage of stearic acid. "Cage" eggs had a significantly lower percentage ($P < 0.05$) of arachidonic acid (C20:4, 1.75 ± 0.22) than had "barn-laid" eggs (1.91 ± 0.14) but the differences had no effect on the total percentages of polyunsaturated fatty acids, which were similar in the 3 production types. The ratio ώ-3 : ώ-6 was marginally but significantly higher ($P < 0.05$) in "cage" eggs (0.10 ± 0.02) than in "free-range" eggs (0.09 ± 0.01).

4. Discussion

The results of the present analysis show that little difference exists in the fatty acid composition of eggs that are produced by conventional or organic methods. Organic eggs have a small although statistically higher ($P < 0.05$) percentage of saturated fats than have conventional eggs, mainly due to higher amounts of palmitic and stearic acids. Within egg type, differences in the contents of saturated fat were observed in a sub-analysis of conventional eggs based on housing conditions. Eggs produced by caged hens contained a significantly lower percentage of saturated fats, mainly due to lower levels of stearic acid, as compared to "barn-laid" or "free-range" eggs. The magnitude of the difference in saturated fat, when comparing conventional with organic eggs, and within conventional eggs, was small and similar to that reported previously (Hidalgo et al., 2008). The present findings are in contrast to those of Cherian et al. (2002) who reported no effect of organic production method on egg fatty acid composition; the lack of concordance may be related to the relatively smaller sample size used in that study.

Omega-3 eggs appear to show the greatest difference in a range of fatty acids. In particular, omega-3 eggs have significantly lower levels of myristic and palmitic acids, resulting in a lower percentage of saturated fats, and a significantly higher percentage of ALA, DHA, and total omega-3 fatty acids. Correspondingly, the ώ-3 : ώ-6 ratio was significantly higher in omega-3 eggs than in organic and conventional eggs.

The total fat content in the egg yolks was significantly lower in the omega-3 eggs than in organic and conventional eggs. Egg weight and eggshell weight (as a percentage of total weight) were significantly different amongst the egg types. It has been reported previously that diet, hen age, strain and other environmental factors influence the size and composition of the eggs (Scheideler, Jaroni, & Froning, 1998). These variables could not be controlled in the present analysis, which was a consumer survey of products available in retail outlets and, as such, specific characteristics of the laying hens are not known.

The manipulation of hens' diets to increase the levels of omega-3 fats in eggs has been demonstrated by incorporating fish oil (Navarro, Saavedra, Borie, & Caiozzi, 1972) or flax seed (Ferrier et al., 1995) in the feed. Omega-3-enriched eggs, particularly through their content of DHA, may confer metabolic advantages that are similar to those produced following the consumption of fish oils. When consumed by humans, egg-derived omega-3 fats have been shown to be bioavailable, as demonstrated by their incorporation in blood platelet phospholipids (Ferrier et al., 1995), and their ability to decrease risk factors for heart disease (Oh, Ryue, Hsieh, & Bell, 1991). The levels of omega-3 in eggs can be naturally high in some "free-range" eggs (Simopoulos & Salem, 1989) and confirm the influence of hens' diets on egg composition. In the present study "free-range" eggs contained similar quantities of fatty acids, including omega-3 fats, as do eggs from other conventional production systems.

The effects of egg consumption on risk factors for metabolic disease and heart disease have been well studied. Large-scale studies in humans (Dawber, Nickerson, Brand, & Pool, 1982; Hu et al., 1999) and reviews of the literature (Kritchevsky & Kritchevsky, 2000) concluded that the consumption of one egg per day is unlikely to have an impact on cardiovascular disease risk in non-diabetic individuals. Egg consumption has been shown to promote satiety (Vander Wal, Marth, Khosla, Jen, & Dhurandhar, 2005) and raise the concentration of high density lipoprotein-cholesterol in overweight subjects consuming a low-fat diet, contributing to a large decrease in the numbers of these subjects classified as having the metabolic syndrome (Mutungi et al., 2008).

Consumer preferences for foods derived by particular production methods may be driven by environmental factors (Shepherd, Magnusson, & Sjödén, 2005; Zhao et al., 2007), perceived benefits to health (Zanoli & Naspetti, 2002; Zhao et al., 2007) or advice from some health professionals (Ojha, Amanatidis, Petocz, & Samman, 2007). The consumption of omega-3 eggs is likely to make a significant contribution toward the recommended target intake of long chain polyunsaturated fatty acids (Nutrient Reference Values for Australia and New Zealand, 2006); however, the small differences in fatty acids that were observed between organic and conventional eggs are unlikely to have any significant metabolic effect on the consumer.

Conflict of interest statement

None of the authors have any conflict of interest. SS designed the study, evaluated the data and wrote the manuscript; FPK collected data and drafted a preliminary report; LMC, MJF, ZIA and JLP provided technical assistance; PP evaluated the data and assisted with drafting the manuscript.

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