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Egg yolk fatty acid profile of avian species - influence on human nutrition

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Summary

Lipids are an important nutritional component of the avian egg. A review of the literature was completed to determine the fatty acid compositions in egg yolk from some avian species. Additionally, the nutritional influence of lipid and lipoproteins content in the plasma of male participants during 30-d feeding was discussed. The ostrich eggs had the highest unsaturated fatty acid and the lowest cholesterol content vs. other avian species. Ostrich had a higher proportion of 18:3n-3 ($p<0.01$) vs. other species. Chicken yolk numerically contained much higher levels of 22:6n-3 than were found in turkeys, quails and geese but the amount of 22:6n-3 in ostrich egg was lower by comparison with species ($p<0.01$). After the storage of eggs at the room temperature, there was a notable loss of vitamin E (vitE) in the yolks of all species and this decrease was marginal ($p<0.01$) in ostrich compared with other species. There were significant ($p<0.05$) increases in plasma LDL of all male subjects. Plasma HDL decreased ($p<0.05$) only in men that were fed chicken or ostrich eggs daily. Consumption of different species' eggs had no influence on the total male plasma cholesterol and triglyceride. LDL-C : HDL-C increased ($p<0.05$) after goose and turkey egg consumption. Consumption of one egg/mth by healthy human subjects had no effect on serum total cholesterol and triglyceride. The LDL-C:HDL-C ratio (which is a strong predictor of coronary heart disease risk) increased, although non-significantly, by consuming chicken, quail and ostrich egg.

Keywords: Avian species, men plasma, fatty acid, vitamin E, egg cholesterol

Abridged title: Egg yolk fatty acids

Introduction

Quality of foodstuffs produced by agricultural animals becomes increasingly important with growing consumer awareness for healthy aspects of food. These aspects do not only include pathogens or traces of contaminants but also the composition of the food itself is an important characteristic of its nutritional value (Mennicken et al., 2005). The egg is composed of structures that support the developing avian embryo. Additionally, the nutritional quality of eggs for human consumption is important (Surai et al., 1999; Austic, 2008). Lipids form over 60% of the yolk's dry matter; which supports the development of the chick (Noble and Cocchi, 1990).

The polyunsaturated fatty acyl content of current diets formulated for domestic laying birds usually consists mainly of linoleic acid (18:2n-6) with a lesser amount of α -linolenic acid (18:3n-3) (Surai et al., 1999). These two unsaturated fatty acids and their long chain derivatives are important components of animal and plant cell membranes (da Silva et al., 2009). The chicken has the ability to change a proportion of these C18 precursors into C20-22 polyunsaturates. Therefore Dietary 18:2n-6 acts as the precursor of yolk 20:4n-6 whereas 18:3n-3 is the precursor of yolk 22:6n-3 (Surai et al., 1999; Mennicken et al., 2005).

Noble et al. (1996) carried out a comparative study on lipid composition of egg yolks from entirely wild and farmed ostriches. There were considerable differences in fatty acid profile; particularly, linolenic acid was 80% less in eggs of farmed ostriches than in eggs of wild birds. Some factors such as species, age and body fat content of the hens affects the fatty acid profile in the egg (Washburn, 1990; Scheideler et al., 1998). Moreover, this is a clear indication that there is genetic variability enabling the increase of the n-3 PUFA content or decrease the n-6:n-3 PUFA ratio in the egg yolk (Mennicken et al., 2000) for example Mennicken et al. (2005) indicated that quail are able to enrich C20:4n-6 and C22:6n-3 in the egg yolk. In other study Millet et al. (2006) examine the effect of isocaloric substitution of animal fat with NutriOmega3 FO (stabilised fish oil with standardised concentrations of C22:6n-3 (11% of fatty acids) and C20:5n-3 (13% of fatty acids)) on lipid profile of eggs in Araucana hens, Lohmann Selected Leghorn and ISA Brown hens. They found an association between breed and diet in yolk fatty acid content for C18:4n-3 and C22:5n-3 but not for other fatty acids on the other hand both dietary fat source and breed the egg yolk fatty acid profile. Egg yolk cholesterol level didn't differ by dietary fat but the effect of breed on yolk cholesterol was significant so that the Araucana eggs had significantly greater cholesterol content than the commercial hybrids ($p < 0.05$; Millet et al., 2006). Also, in Steinhilber (2005) study the effect of layer strain (but not fat source) on egg yolk cholesterol was significant. They observed that the birds with high egg production rates have lower yolk cholesterol level than the birds with low egg production rate. Both strain and dietary fatty acid composition influenced the yolk fatty acid profiles. The strains Bresse, Italian and Marans strains had a very low level of egg yolk α -linolenic and linoleic acid, but oleic acid level was significantly high in all 3 strains. As mentioned above, lipid is the main portion of egg yolk so, it has been reported that the decrease of shelf life of the eggs during

storage was mainly due to the lipid oxidation of egg yolk and overall reduction in egg quality (Ahn et al., 1995). Therefore, to maintain egg quality and fatty acid stability during storage, it is essential to prevent or minimize lipid oxidation (Hayat et al., 2010). α -tocopherol, has been extensively used in feeds as a natural antioxidant which is easily deposited in the egg yolk (Chen et al., 1998; Grashorn 2005). Meluzzi et al., (2000) reported that 28 days of storage at room temperature (20-25°C) did not alter the yolk fatty acid profile of Hy-Line Brown hens that fed on different doses of dl- α -tocopheryl acetate (0, 50, 100, and 200 mg/kg) and n-3 PUFA; moreover, they concluded that the levels of vitE still remained very close to those observed in fresh egg.

During the past four decades there have been many articles published concerning the egg consumption effect on the serum lipid profile of human subjects; there are, however, contradictory reports. For example, certain studies reported that egg consumption had no effect on serum concentrations of total cholesterol nor the relation between egg consumption and the risk of developing coronary heart diseases (CHD) (Kummerow et al., 1977; Flynn et al., 1979; Dawber et al., 1982; Oh and Miller, 1985; Hu et al., 1999; McNamara, 2000; Goodrow et al., 2006; Nakamura et al., 2006; Lee and Griffin, 2006). In addition other studies have shown that consuming the whole egg or an egg yolk increases blood LDL-C (Applebaum-Bowden et al., 1979; Hopkins, 1992; Clarke et al., 1997; Handelman et al., 1999; Natoli et al., 2007), HDL-C (markedly increase: Beynen and Katan, 1985; small or negligible increase: Applebaum-Bowden et al., 1979) or both of LDL-C and HDL-C (Greene et al., 2005), in addition to the risk of CHD (Weggemans et al., 2001). Mensink et al. (2003) evaluated the science to validate biomarkers linking diet and cardiovascular disease risk, and concluded that an extensive amount of research has demonstrated unequivocally that serum cholesterol is a biomarker for cardiovascular disease risk. The American Heart Association's latest nutrition recommendations do not limit the number of eggs that can be eaten, as long as one's total cholesterol intake is limited to no more than 300 milligrams per day (Kritchevsk, 2004).

Accordingly, as there are few comparative studies on the egg fatty acid content of various farm poultry species (*Gallus gallus domesticus*, *Coturnix Coturnix Japonica*; *Anser anser*; *Meleagris gallopavo* and *Struthio camelus*) and their influence on human serum lipid, the present study was carried out to compare the yolk fatty acid profiles of some avian species and vitE content of fresh and stored eggs (30 days of storage at 20±2°C temperature); on the other hand there have been

few comparative studies on the relationship between different avian species eggs consumption and the cholesterol, triglyceride and lipoprotein level in humans population, so in the present study we also evaluated this effect.

Materials and Methods

Trail

Mature female birds, chickens (Leghorn; *Gallus gallus domesticus*), quails (Japanese quail; *Coturnix Coturnix Japonica*), geese (white strain; *Anser anser*), turkeys (Iranian native strain; *Meleagris gallopavo*) and ostriches (Black neck strain; *Struthio camelus*) were fed a corn-soy based diet formulated for each species based on their own requirement. All diets contained the same concentration of vitE premix. The diets were formulated to meet minimum nutrient requirements of each species except ostrich, as established by the National Research Council (NRC, 1994). As there is no specific reference about the ostrich nutrition requirements and as the complementary researches in the world are still under consideration so we used some references for ostrich diet formulation (Cilliers et al., 1994; Cilliers et al., 1997; Cilliers, 2004; Cooper et al., 2004). Dietary compositions are shown in Table 1. Chickens (commercial farm) and quails (East Azarbaijan Animal Science Research Centre, Bonab-Iran) were housed in 15 battery cages (3 and 12 chicken and quail respectively per cage) at 22-24°C. Geese (East Azarbaijan Animal Science Research Center, Malekan-Iran) and turkeys (East Azarbaijan Animal Science Research Center, Tatar-Iran) were kept in rooms containing individual pens (15 wood shavings litter pen 3 birds each one). All birds except ostrich received 16 L (light) : 8D (dark) at the egg production phase. 5-year-old ostriches (Ratite Research and Development Institute, Tehran-Iran) were kept in 15 out-door units with shelter comprising 2 hens and 1 cock. For determination of cholesterol and fatty acid composition, eggs were gathered from the birds at the middle of their egg production period. The eggs were weighed, and then the egg yolk was separated from the albumen with an egg separator and then carefully rolled on a damp paper towel to remove any adhering albumen. The chalazae were also removed of yolk before weighing the yolk (Golzar Adabi et al., 2006). The total fat of diets and yolks was extracted according to Folch et al. (1957) and methylated with 5% boron trifluoride methanol complex in methanolic solution. The lipid profile was determined by means of gas chromatography equipped with a BPX70 capillary column (SGE capillary column; length, 30 m; I.D., 0.33 mm; 70% cyanopropyl

polysilphenylene-siloxane stationary phase) film, and a flame ionization detector. The operating conditions of the gas chromatograph were as follows: the initial temperature was 170°C for 8 min, increasing by 3 °C/min to 180°C, the temperature was increased by 5°C min⁻¹ to 190°C and remained stable at final temperature for 25 min, the injection temperature was 220°C and make up was 15 µl/S. The FA percentage was integrated and then calculated by means of direct normalization of the peak areas. Each FA was identified in the form of a methyl ester by comparing the retention times with the standard acquired at Sigma Interlab A.S¹. The concentration of egg yolk cholesterol was determined by using commercial kits (Ziestchem diagnostics Tehran, Iran). For determining egg cholesterol the yolk samples (1 ml) were mixed with 0.05 molar of NaOH (25ml), neutralized with 0.25 normal of HCl, and then assayed (Luhman et al., 1990; Golzar Adabi et al., 2006). VitE content of egg yolk was determined based on Meluzzi et al. (2000).

Human trail

The effect of daily intake of above mentioned different species' eggs on serum cholesterol, triglycerides and lipoproteins was investigated in 4 men per treatment with a mean age of 55 years old (range: 50-62 years old) who were currently not taking cholesterol-lowering medication and had an average waist circumference of 87± 6.8 cm, and average body weight 79± 6.5 kg with light clothes and bare feet. There were no dropouts during the study. The subjects were non-smokers and were not using any medication. Persons with a history of active small bowel disease or resection, atrophic gastritis, insulin requiring diabetes, alcoholism, pancreatic disease, or bleeding disorders were excluded from the study. Eligible male participants were randomly assigned to consume one egg in their daily diet for 30-d and during the experiment subjects were instructed to continue to consume their regular diet but to abstain from consuming eggs and egg products outside of those provided by the study (Greene et al., 2006; Golzar Adabi et al., 2010). The blood lipids in all subjects were determined at the commencement of the study in order to avoid subjective differences amongst blood lipids. In order to feed the subjects with the same level of egg yolk and albumen but considering the differences between weight of various poultry species' eggs, we decided to separate and weigh the yolk and albumen of egg after hard boiling and then the same weight of chicken yolk and albumen was prepared from

¹ Interlab S.A. Istanbul, Turkey.

other species' eggs. Chicken egg consists of 60 and 28% albumen and yolk, respectively (Mine, 2008). Therefore in Jumbo size fresh chicken egg with 75 g weight the amount of albumen and yolk are almost 45 and 21 g respectively.

Blood samples collected 1 week prior to supplementation. In addition, blood samples (morning blood samples were collected after an 8 hours fasting) were collected at the end of this period (Golzar Adabi et al., 2010). The effect of a feeding eggs of different species (one egg per day for 30-d as same weight as Jumbo Leghorn egg) on the total cholesterol (TC), low density lipoprotein cholesterol (LDL-C), high density lipoprotein cholesterol (HDL-C) and triglycerides (TG) concentrations and LDL-C:HDL-C ratio were examined. TC was determined by enzymatic methods (Allain et al., 1974), and HDL-C was measured in the supernatant after precipitation of apo-B-containing lipoproteins (Warnick et al., 1982). TG concentrations were determined using Roche-Diagnostics kits, which adjust for free glycerol (Carr et al., 1993). LDL-C was determined using the Friedewald equation [LDL-C = total cholesterol - HDL-C - (triglycerides/5)] (Friedewald, 1972). The experimentation procedure was performed in accordance with Biosecurity Rules of Iran Agricultural Ministry and The National Committee for Ethics in Science and Technology.

2.3. Statistical analyses

The data yolk cholesterol, fatty acid and vitE content of egg analyzed by general linear model and plasma TC, TG, HDL, LDL and LDL-C:HDL-C ratio of the participants were analyzed by mixed models procedure of SAS software (SAS institute 1986, SAS Institute Inc., Cary, NC, USA). All percentage data were subjected to arcsin square root transformation (Steel and Torrie, 1960). All data were presented as mean±SD. When necessary mean separation was accomplished by using Duncan's multiple-range test (Duncan, 1955) a probability p-value of less than 0.01 and 0.05 was considered significant.

Results

The fatty acid compositions of the yolk lipids were affected by the species (Table 2) so that there were no differences in myristic, eicosapentaenoic, docosapentaenoic acid and n-3 PUFA content of different species. Of course eicosapentaenoic acid did not detect in chicken, quail and turkey eggs (Table 2). The concentration of saturated fatty acids was affected only by species for palmitic and stearic acid, indicating that the significantly lowest ($p<0.01$) concentrations were

seen for ostrich and the highest ($p<0.05$) concentrations occurred for ostrich and chicken, respectively. Ostrich egg had the highest ($p<0.01$) oleic acid (C18:1n-9) in contrast to the turkey egg had the highest ($p<0.05$) vaccenic acid (C18:1n-7) (Table 2). The fatty acid profile of quail egg was very similar to that of the chicken egg (Table 2). Major findings in PUFA level of eggs were that the proportion of linolenic and arachidonic acids were higher ($p<0.01$) in the yolk of the ostrich egg than in the yolk of the other species. Only do docosahexaenoic fatty acid was the lowest ($p<0.01$) in the yolk of the ostrich eggs. It should be mentioned that linolenic acid is the predominate n-3 fatty acid in ostrich egg ($p<0.01$). On the other hand, the predominant n-6 fatty acid was linoleic with the highest level in chicken and ostrich eggs ($p<0.05$).

The n-6:n-3 fatty acid ratio of eggs ranged from 15 to 19. The geese eggs had the lowest ratio at 15.62 ± 1.04 ($p<0.01$; Table 2). Other differences were also found in the current study; for example, the ostrich egg lipid contained the highest level of total monounsaturated fatty acids (the sum of the oleic and vaccenic acid) ($p<0.05$) and total PUFA (the sum of the linoleic, linolenic, arachidonic, eicosapentaenoic, docosapentaenoic and docosahexaenoic) ($p<0.01$; Table 2). The yolk cholesterol levels were significantly lower ($p<0.05$) in the ostrich egg (9.75 mg g^{-1} of yolk) than those in the other species. The cholesterol concentration of the quail (*Coturnix coturnix Japonica*) egg was very similar to that of the chicken egg in terms of mg g^{-1} of yolk (Table 3). This finding is in agreement with Bragagnolo and Rodriguez-Amaya (2003) who demonstrated that the cholesterol content of the quail egg in mg g^{-1} of yolk was very similar to that of the chicken egg and reported that the overall average of the cholesterol content was 12.0 and 12.1 mg.g^{-1} of chicken and quail egg yolk, respectively.

The proportion of vitE in both fresh and stored eggs are shown in Figure 1 & 2. The fresh eggs of chicken, quail and turkey contained the same proportion of vitE by comparison with the other two species. The concentration of plasma LDL-C after the egg period in subjects varied when compare with the baseline data so that, when all data related to before and after egg feeding period were evaluated, there were significant ($p<0.05$; Table 4) increases in LDL-C at the end of egg period in all treatments. Plasma HDL-C decreased ($p<0.05$; Table 4) only in subjects that received chicken or ostrich eggs daily. At the end of the egg period LDL-C:HDL-C increased ($p<0.05$; Table 4) in men fed goose or turkey egg.

Discussion

The successful development of the embryo is dependent upon the presence of both n-6 and n-3 polyunsaturates in the yolk lipids in amounts and proportions which are appropriate to meet the demands of the various embryonic tissues (Speake et al., 1999). On the other hand it has previously been shown that the PUFA profile of the yolk is highly dependent on the types of the PUFAs present in the birds' diets (Hargis and Van Elswyk, 1993; Farrell, 1998; Ayerza and Coates, 2000; da Silva et al., 2009). Di Meo et al. (2003) investigated the physical and chemical quality of ostrich eggs during the laying season and reported that compared with the chicken's egg, the ostrich egg has similar chemical and nutritive characteristics, but a higher unsaturated : saturated fatty acid ratio, and lower cholesterol content.

The mean cholesterol content of chicken yolk (12-19 mg g⁻¹; Reiner et al., 1995; Bragagnolo and Rodriguez-Amaya, 2003); ostrich (ca. 10.8 mg g⁻¹ of yolk; Di Meo et al., 2003; Meluzzi et al., 1995), quail (8.5-10.9 mg g⁻¹ of yolk; da Silva et al., 2009); hard boiled goose egg (15.8-17.5 mg g⁻¹ of yolk for white and African goose respectively; Bair and Marion, 1978); and turkey (16.8-18.1 mg g⁻¹ for domestic and wild turkey respectively; Maurice et al., 1994) were reported. The cholesterol level in eggs from different species varies with breed, age of the hen, egg and yolk weight and diet (Bragagnolo and Rodriguez-Amaya, 2003). Even, Chavous et al. (1965) tested the genetic variation in egg yolk cholesterol and found a significant difference between 20 breeding combinations of commercial laying hens.

The n-6:n-3 fatty acid ratio of egg yolks of the current investigation is higher compared with the some of the other trials (da Silva Filardi et al., 2005; Kralik et al., 2008; Ceylan et al., 2011). In this regard we did no inclusion of vegetable oil in the experimental diets and the large part of diet consisted of corn which is rich in linoleic acid (18: 2n-6) (Baur Jr and Brown, 1945; Guclu et al., 2008; Kamal and Klein, 2007) (Table 1). The high proportion above-mentioned compare vs. other studies can be related to diet composition; because fatty acid profile of the diets have major effect on yolk fatty acid composition in different poultry species (Gulcu et al., 2008; Oliveira et al., 2010; Ceylan et al., 2011). In Milinsk et al. (2003) study the amount of n-6:n-3 fatty acid ratio of yolk after 16 weeks feeding by sunflower oil (which is an important source of n-6) was 17.7 and 12.0 % in Red Lohman and White Lohman hens, respectively. In other study the n-6:n-3 ratio of the egg was reported 27.3, 28.9 and 39.2 for regular white-shelled eggs, certified organic free-range brown eggs and naturally nested, uncaged hens fed diets with no steroids or

no stimulants, respectively (Cherian et al., 2002). On the other hand the dietary patterns of the birds are different so that Klasing (1998) classified the birds according to a variety of feed consumption schemes. As it is shown in table 1 for example chicken and quail diet is consisted of grains and seeds which are rich in 18: 2n-6 but goose, turkey and especially ostrich diet has different levels of grass with a great amount of galactolipids which 60 to 90 % of their whole fatty acids are 18: 3n-3 (Speake et al., 1999).

Jiang et al. (1994) supplemented the feed with 200 mg vitE.kg⁻¹. The α -tocopherol concentrations in egg yolk were 18.8 mg 100 g⁻¹ and 24.6 mg 100 g⁻¹ egg yolk, respectively. Also, in the present investigation, the changes in the vitE content of eggs after the 30-d storage are illustrated (Figure 2). Thereafter, the vitE content attenuated by 10 to 12%. In the study of Meluzzi et al. (2000) after 28-d of storage, the levels of vitE remained still very close to those observed in fresh eggs, suggesting that the vitamin was not used to prevent lipid oxidation in the yolk. In other studies, however, storage of eggs led to marked reductions in egg α -tocopherol ($p < 0.05$) (Grune et al., 2001; Hayat et al., 2010). The effect of dietary α -tocopheryl acetate supplementation on enhancing lipid stability in egg yolk has been previously reported (Chen and Hsu, 2006; Bourre and Galea, 2006). Nevertheless, earlier studies suggested that altering the tocopherol content of eggs is dependent upon the stage of life cycle, agronomic and genetic factors, season, weather, harvesting methods, processing procedures, storage environment, and time periods of storage (Bauernfeind and Desai, 1977).

Another part of the present study investigated the effect of various species eggs on men plasma lipid and lipoprotein. Our results, such as some other clinical studies showed that the egg consumption and serum cholesterol concentrations are not directly related (Chenoweth et al., 1981; Vorster et al., 1992; Ginsberg et al., 1994; Hu et al., 1999; Kerver et al., 2002; Chen and Watson, 2002; Djoussé and Gaziano, 2008). One hundred and sixteen male candidates aged 32-62 years-old consumed two whole fresh eggs daily in their regular diets for 3 months and also eliminated eggs from their diets for a further 3 months. No significant increase in mean serum cholesterol was found, nor was there a significant association of dietary cholesterol intake with serum cholesterol (Flynn et al., 1979).

Cholesterol is mostly circulated in the liver in the form of LDL-C. Liver cells LDL-C receptors actively take up the LDL-C for metabolism. Other extra-hepatic tissues also contain LDL-C

receptors that are not as active as the liver cell receptors. Thus, the plasma concentration of LDL-C is greatly affected by the rate at which LDL-C is formed and the rate of uptake by LDL-C receptors. Therefore, genetics plays a role here by determining the rate of activity of LDL-C receptors (Vaghefi, 2002). In controlled metabolic studies, ingestion of cholesterol by eating egg yolks or whole eggs raises the serum LDL-C level (Hopkins, 1992; Clarke et al., 1999). On the other hand, the effects of egg consumption on raising HDL levels have been observed in some studies (Schnohr, 1994) but some studies also reported no particular effects (Ginsberg et al., 1994). In a study conducted by Greene et al. (2005) it was shown that both plasma LDL-C and HDL-C significantly ($p < 0.05$) increased in men/women aged 29-60 yr. by consuming 3 eggs/d, and there were no significant alterations in the ratios of LDL-C:HDL-C. In an investigation by Goodrow et al. (2006) the study serum concentrations of TC, LDL-C, HDL-C and TG were not affected by consuming 1 egg/d for 5 wk in men and women >60 yr. old. Zanni et al. (1987) suggested that diet cholesterol has no effect on plasma TG levels; on the other hand in the Framingham study and some other researches no relation was found between TC levels, resulting from increased egg consumption, and the incidence of CHD (Dawber et al., 1982; Gramenzi et al., 1990; Greene et al., 2005). The ratio of LDL-C:HDL-C is a strong predictor of CHD risk, so changes in both variables will produce changes in this ratio. It is necessary mentioned that a wide variability in individual response to dietary cholesterol (hyperresponders vs. hyporesponders) has been reported. It has been suggested that among hyper-responders, the dietary cholesterol from eggs leads to a modest increase in serum LDL and HDL cholesterol and no effect on LDL/HDL ratio (Djoussé and Gaziano, 2008). Chen and Watson (2002) reported that the relationship between egg intake, serum cholesterol, and coronary heart disease are inconsistent. These conflicting results could be attributed to other extraneous factors. For example some of the conflicting results originate from poor design and/or some of them are due to individual differences in the sensitivity of serum cholesterol dietary intake.

Recently Kayikcioglu and Soydan (2009) reviewed egg consumption and cardiovascular health. They discussed that it is not possible to standardize consumption of other dietary sources of cholesterol and saturated/unsaturated fatty acids, carbohydrates and antioxidant vitamins between the groups based only on the comparison of egg consumption. As a result, this reality should be taken into consideration when interpreting the results of these studies. A difference

between our study and the results of Goodrow et al. (2006) about the serum LDL-C, may be related to the greater age of the subjects that participated in the study (mean age: 79 yr.; range: 60-96 yr.). Indeed, there are several studies (Garry et al., 1992; Ferrara et al., 1997) which suggest that serum LDL-C concentrations are attenuated in older populations.

Conclusion

There are a variety of articles on the avian species differences in the fatty acid profile and the cholesterol content of the yolk, and the effect of egg consumption on human subject's blood lipid and lipoprotein concentrations. Yet, it appears that the current investigation is the first to report the effect of consumption of eggs of different species (one egg/day for 30-d) on the lipid and lipoprotein status of the plasma in male participants. Our study demonstrated that:

- 1) Cholesterol and lipid content of the eggs vary among different avian species. The chicken (Leghorn) and quail (Japanese quail) have the same amount of the cholesterol based on mg.g^{-1} of yolk.
- 2) The egg yolk fatty acid profiles of different avian species vary, *e.g.* the ostrich egg has significantly ($p < 0.01$) higher and lower amounts of 18:3n-3 and 22:6n-3, respectively.
- 3) The egg yolk vitE level is attenuated (based on $\mu\text{g g}^{-1}$ of yolk) following 30-d storage at $20 \pm 2^\circ\text{C}$ temperature. It decreases in the ostrich egg yolk, and is minimal in other species.
- 4) Consuming one egg/d for 30-d (ca. same weight as Jumbo size fresh leghorn egg with 75 g weight) increased the LDL-C level in all groups, decreased the HDL-C in the chicken and ostrich group, and increased the LDL:HDL ratio in groups that received goose and turkey eggs.
- 5) In the present study chicken eggs showed no effect on the LDL:HDL ratio but it is worth noting that, in advance, in order to reduce egg intake especially in the healthy person, it is preferred to assess benefits and disadvantages of individual egg consumption.

Conflict of interest

Authors have no conflicts of interest to declare whatsoever.

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Table 1

Composition and nutrient content of the experimental ration (%)

Ingredient(%)	Chicken	Quail	Goose	Turkey	Ostrich
Corn	61.13	56.4	60	60.22	24.96
Soy bean meal	18.35	30.91	16.8	13.6	13.6
Sunflower meal	-	-	-	-	12.32
Wheat	10	5	11	12.12	-
Wheat bran	-	-	-	-	17
Alfalfa	1	-	5.29	7.1	23.14
Salt	0.15	0.15	0.15	0.15	0.43
Di calcium phosphate	0.73	1.07	0.98	1.23	1.37
Min+vit. premix ¹	1	1	1	1	1
DL-methionine	0.06	0.12	-	-	0.25
Oyster shell	7.58	5.35	4.78	4.58	5.93
Calculated analysis	*****	*****	*****	*****	*****
ME(kcal/kg)	2800	2730	2800	2800	2600
Crude protein(%)	14.48	18.96	14.49	13.52	16
Lysine(%)	0.7	0.99	0.74	0.69	0.7

Methionine(%)	0.3	0.42	0.24	0.23	-
Methionine+cyste(%)	0.56	0.74	0.51	0.49	0.5
Ca(%)	3.13	2.37	2.17	2.17	3
P%(nonphytate)	0.24	0.33	0.29	0.33	0.5
Linoleic acid	1.45	1.36	1.4	1.4	1.3
Na	0.14	0.14	0.14	0.14	0.22
Determined fatty acid ^{2,3}	*****	*****	*****	*****	*****
ΣSFA	13.77	12.36	14.82	15.46	14.76
ΣMUFA	29.56	33.67	31.29	31.09	30.65
ΣPUFAs	56.64	53.87	53.98	53.40	54.49
n-6	53.87	51.41	51.39	50.91	51.84
n-3	2.77	2.46	2.59	2.51	2.64
n-6/n-3	19.44	20.89	19.84	20.28	19.63

¹2.5 kg of vitamin mineral premix contain: vitamin A, 6,000,000 IU; cholecalciferol, 1,500,000 IU; vitamin E (dl-alpha-tocopherol acetate), 150 mg; riboflavin, 3,000 mg; pantothenic acid, 7,000 mg; nicotinic acid, 25,000 mg; folic acid, 500 mg; choline chloride, 125000 mg and vitamin B12, 15,000 µg; Mn, 120,000 mg; Zn, 80,000 mg; Fe, 90,000 mg; Cu, 15,000 mg; I, 1,600 mg; Se, 500 mg; and Co, 600 mg.

vitamin mineral premix per ton of ostrich diet: vitamin A, 15,000,000 IU; cholecalciferol, 25,000,000 IU; vitamin E (dl-alpha-tocopherol acetate), 150 mg; vitamin K3, 3,000 mg; vitamin B1, 2,000 mg; riboflavin, 8,000 mg; pantothenic acid, 18,000 mg; nicotinic acid, 45,000 mg; folic acid, 100 mg; choline chloride, 500000 mg; Biotin, 100 mg and vitamin B12, 100, mg; MG, 40,000 mg; Mn, 120,000 mg; Zn, 90,000 mg; Fe, 35,000 mg; Cu, 15,000 mg; I, 1,000 mg; Se, 300 mg; and Co, 100 mg (Cilliers et al., 1997).

²The values presented are means of triplicate determinations.

³ΣSFA=total saturated fatty acids; ΣMUFA=total monounsaturated fatty acids; ΣPUFA=total polyunsaturated fatty acids.

Table 2Fatty acid composition of eggs (%)¹.

Fatty acid ²	Experimental diet						SEM ³	P
	Chicken	Quail	Goose	Turkey	Ostrich			
C14:0	Myristic	0.55	0.63	0.68	0.65	0.612	0.024	-
C16:0	Palmitic	29.31 ^b	30.40 ^b	32.34 ^a	30.92 ^b	23.17 ^c	0.475	**
C18:0	Stearic	10.51 ^a	8.98 ^b	8.28 ^b	8.97 ^b	10.13 ^a	0.225	*
C18:1n-9	Oleic	42.61 ^b	41.62 ^b	41.57 ^b	41.50 ^b	44.20 ^a	0.567	**
C18:1n-7	Vaccenic	1.02 ^b	2.43 ^b	2.01 ^b	3.01 ^a	2.05 ^b	0.031	*
C18:2n-6	Linoleic	13.65 ^{ab}	12.80 ^b	11.61 ^b	12.35 ^b	14.16 ^a	0.328	**
C18:3n-3	Linolenic	0.29 ^b	0.31 ^b	0.45 ^b	0.32 ^b	1.01 ^a	0.036	*
C20:4n-6	Arachidonic	1.51 ^c	1.41 ^c	2.45 ^b	1.32 ^c	4.37 ^a	0.046	*
C20:5n-3	Eicosapentaenoic	nd	nd	0.06	nd	0.05	0.011	-
C22:5n-3	Docosapentaenoic	Trace	0.07	0.04	0.02	0.03	0.007	-
C22:6n-3	Docosahexaenoic	0.54 ^a	0.44 ^a	0.35 ^a	0.38 ^a	0.02 ^b	0.078	*
ΣSFA		40.37 ^a	40.01 ^a	41.3 ^a	40.54 ^a	33.91 ^b	0.321	*
ΣMUFA		43.63 ^b	44.05 ^b	43.58 ^b	44.51 ^b	46.25 ^a	0.412	*
ΣPUFA		15.99 ^b	15.03 ^b	14.96 ^b	14.39 ^b	19.64 ^a	0.128	**
ΣPUFA n-6		15.16 ^b	14.21 ^b	14.06 ^b	13.67 ^b	18.53 ^a	0.271	*
ΣPUFA n-3		0.83	0.82	0.9	0.72	1.11	0.033	-
C16:n-3		18.26 ^a	17.33 ^a	15.62 ^b	18.98 ^a	16.69 ^{ab}	0.751	*

^{a,b,c}Values within the same row with no common superscript are different; *P<0.05 or **P<0.01.

¹Results expressed as a percentage of the total fatty acids. The values are presented as mean±S.D. of 5 observations, each one in triplicate per species.

²ΣSFA=total saturated fatty acids; ΣMUFA=total monounsaturated fatty acids; ΣPUFA=total polyunsaturated fatty acids; ΣPUFA-n6 = C18:2n-6 + C20:4n-6; ΣPUFA-n3 = C18:3n-3 + C20:5n-3 + C22:5n-3 + C22:6n-3

³SEM= standard error of mean.

nd= not detected.

Table 3

Comparison of the cholesterol concentration of egg yolk (mg g^{-1} of yolk) from different avian species.

Treatment	Weight (g)		Cholesterol ¹
	Egg (g)	Yolk (g)	mg g^{-1} of yolk
Chicken	53±4.2	14.8±2.1	12.25 ^b
Quail	9.6±0.6	3.4±0.23	11.12 ^b
Goose	131.5±2.01	49.18±3.21	15.81 ^a
Turkey	85.2±3.69	25.5±1.31	13.35 ^{ab}
Ostrich	1330.5±62.2	314.45±34.1	9.75 ^c
SEM ²	-	-	0.18
P	-	-	*

a,b,c Values
same
no common
are different

within the
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superscript

significantly; *P<0.05

¹The values are presented as mean±S.D. of 10 different individuals' observations, each one in triplicate per species.

²SEM= standard error of mean.

Table 4

Comparison of plasma lipid concentration between before and after ingestion of different avian species one fresh egg per day in healthy adult men¹.

Treatments	Item (mg dl ⁻¹)				
	TC	TG	LDL-C	HDL-C	LDL-C:HDL-C
CHICKEN					
Before	185.00±1.59	85.55±1.14	114.30±1.94 ^b	53.58±0.50 ^a	2.13±0.05
After	186.83±1.05	84.89±1.21	117.25±1.31 ^a	52.59±0.51 ^b	2.22±0.04
QUAIL					
Before	183.55±1.76	86.45±0.45	109.47±3.07 ^b	56.78±1.49	1.92±0.10
After	185.78±0.83	85.58±3.73	114.21±1.48 ^a	54.44±2.03	2.10±0.10
GOOSE					
Before	183.81±1.33	86.19±1.29	112.76±1.96 ^b	53.80±0.81	2.09±0.06 ^b
After	187.00±1.13	86.85±0.77	118.145±2.27 ^a	51.49±1.91	2.29±0.12 ^a
TURKEY					
Before	183.96±2.75	83.76±0.56	110.08±4.14 ^b	57.12±2.41	1.93±0.14 ^b
After	187.45±1.56	84.61±0.71	116.81±1.09 ^a	53.71±1.64	2.17±0.09 ^a
OSTRICH					
Before	186.01±0.99	86.88±1.26	109.19±0.77 ^b	59.44±0.73 ^a	1.84±0.03
After	186.53±0.69	87.65±1.24	114.01± 1.43 ^a	54.98±1.43 ^b	2.08±0.20

¹Values are means±SD

²TC= Total cholesterol; TG= Triglycerides; HDL-C= High density lipoprotein cholesterol; LDL-C= Low density lipoprotein cholesterol.

^{a,b}Values within the same column with no common superscript are different significantly; P<0.05.

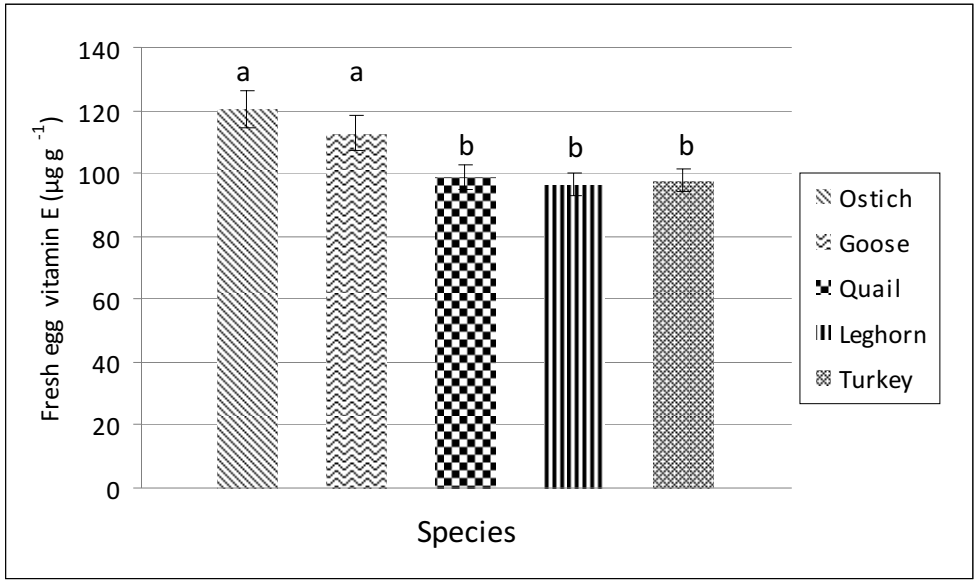


Figure 1. VitE ($\mu\text{g g}^{-1}$ of yolk) contents of fresh egg from different avian species; ($p < 0.05$)

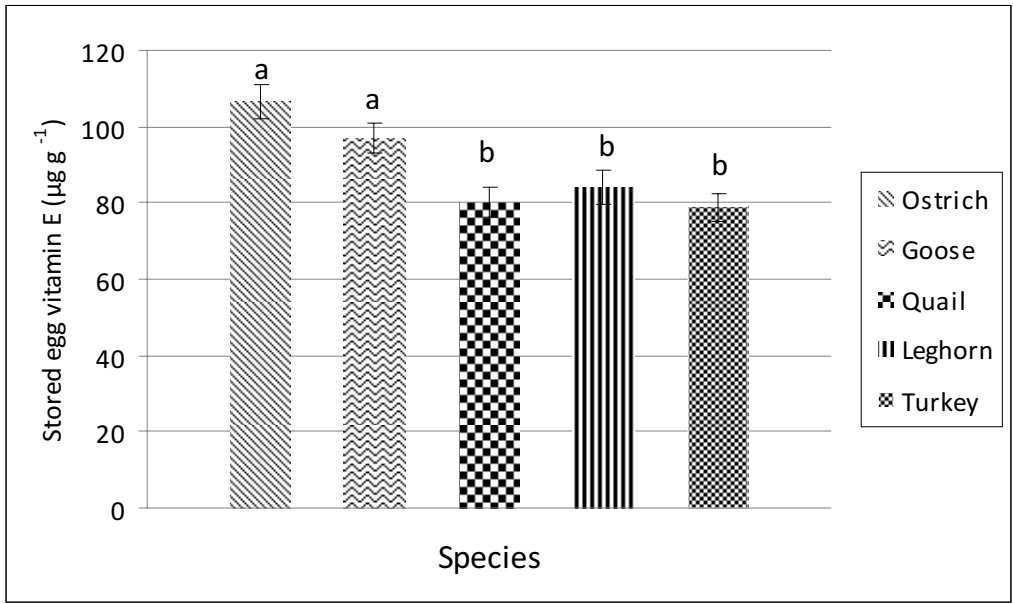


Figure 2. VitE ($\mu\text{g g}^{-1}$ of yolk) contents of stored egg from different avian species; ($p < 0.01$)