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Characteristics of Egg Parts, Chemical Composition and Nutritive Value of Japanese Quail Eggs – a Review*

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All nutrients including proteins, lipids, vitamins, minerals and growth factors required by the developing embryo, as well as a number of defense factors, can be found in avian eggs. Eggs are also a source of other substances with biological functions and activities inter alia immune proteins and enzymes. Although chicken egg consumption is currently at the highest level, eggs from other species are also becoming popular. Since our knowledge about Japanese quail eggs is still limited, the aim of this review was to shed light on characteristics of egg parts, chemical composition and nutritive value of quail eggs.

Key words: Japanese quails, eggs, morphology, chemical composition.

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The avian egg is an important source of nutrients, containing all of the proteins, lipids, vitamins, minerals, and growth factors required by the developing embryo, as well as a number of defense factors to protect against bacterial and viral infection. Moreover, eggs contain substances with biological functions and activities, i.e. immune proteins, enzymes, etc. (HANSEN *et al.* 1998; NOWACZEWSKI *et al.* 2013), characterized by antiadhesive and antioxidant properties, antimicrobial activities, immunomodulatory, anticancer, and antihypertensive activities, protease inhibitors, nutrient bioavailability, and functional lipids, highlighting the importance of egg and egg components in human health and in disease prevention and treatment (KOVACS-NOLAN *et al.* 2005).

Although chicken eggs are currently most commonly eaten by humans, the eggs from other birds are also used for daily consumption. For example Japanese quail eggs are gaining popularity in Europe and America, ostrich eggs in South Africa (HORBAŃCZUK *et al.* 2008) and duck eggs in southeast Asian countries. It should be underlined that recently there is growing interest in alternative bird species including guinea fowl, ostrich, emu, pheasant and Japanese quail since these birds provide valuable eggs and meat which are called niche products (HORBAŃCZUK *et al.* 1998; SALES & HORBAŃCZUK 1998; POŁAWSKA *et al.* 2011, 2012, 2013; CABUK *et al.* 2014). Since our knowledge about Japanese quail eggs is still limited, the aim of this review was to shed light on the morphological and chemical composition, as well as nutritive value, of quail eggs and provide a comparison to eggs of other bird species.

Egg parts

The mean quail egg weight is about 11g (Table 1) and is approximately more than 5 times smaller

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Table 1

Characteristics of quail egg parts as compared to eggs of other bird species (HORBAŃCZUK 2002; KULI & SEKER 2004; KOŻUSZEK *et al.* 2009)

Species	Egg weight (g)	% of egg mass		
		albumen	yolk	shell
Quail	11.3	59.7	32.7	7.4
Chicken	58	55.8	31.9	12.3
Goose	200	52.5	35.1	12.4
Turkey	85	55.9	32.3	11.8
Duck	80	52.9	35.6	12.5
Ostrich	1580	59.8	20.4	19.8
Guinea fowl	40	52.3	35.1	12.6
Pheasant	32.8	58.1	33.0	8.9

Table 2

Chemical composition (%) of eggs from different poultry species (HORBAŃCZUK 2002; DUDUSOLA 2010)

Parameter	Species		
	Quail	Chicken	Ostrich
Albumen:			
Water	87.8	87.9	88.7
Protein	10.4	10.6	8.9
Ash	1.0	0.6	0.9
Yolk:			
Water	49.7	48.7	50.6
Protein	16.0	16.6	15.0
Fat	31.5	32.6	31.3
Ash	1.8	1.0	1.9

than chicken eggs (58 g) and even 100 times smaller than the largest egg (1522 g) of ostrich (HORBAŃCZUK 2002; KUL & SEKER 2004). However, quail egg weight, shape and colour can vary greatly among different females in a population, but are quite specific and consistent for one female. Quail eggs are generally from white to brown in colour and mottled (black and brown spots). The relationship between Japanese quail egg colour, shell quality and internal features was confirmed in some experiments inter alia carried out by TAHA (2011).

About 60% of the mass of the quail egg is comprised by the albumen (NOWACZEWSKI *et al.* 2010a), similarly to ostrich egg. Chicken and turkey egg have a lower percentage content of albumen (56%), and goose and duck even lower (53%). In turn, in quail egg, as well as in chicken, goose, turkey and duck egg, the yolk comprises almost one third of the weight, while only one fifth in ostrich egg. The share of the shell weight in the total mass of quail egg (7.4%) is the lowest compared to other poultry eggs (12%) and especially much lower than in ostrich egg (almost 20%). The most concise characteristic of the egg shape is given by the egg shape index, which for quail egg (75%) is more similar to chicken egg (73-78%) than ostrich egg (82%) (HORBAŃCZUK 2002; KUL & SEKER 2004).

Chemical composition

The chemical composition of quail eggs in comparison to chicken and ostrich egg is presented in Table 2. The quail albumen consists of almost 88% water, 10% protein and 1% ash, and its chemical composition is similar to chicken egg. Ostrich albumen has a slightly lower protein and ash content. In turn, the chemical composition of quail egg yolk is more similar to ostrich and contains lower fat content and higher ash content than chicken egg yolk (HORBAŃCZUK 2002; DUDUSOLA 2010).

GENCHEV (2012) reported that quail egg has a higher content of crude protein in albumen (14.1-14.6%) and lower content of ash in albumen (0.76-0.78%) and yolk (1.1-1.3%) as compared to results presented by DUDUSOLA (2010). SINANOGLOU *et al.*, (2011) obtained a similar result to DUDUSOLA (2010) and GENCHEV (2012) in yolk dry matter content (53.8%), but they reported lower fat and higher ash content (27.45 and 2.63%, respectively) in quail egg yolk.

Cholesterol and fatty acids content

The nutritive value and functional properties of eggs make them an important animal protein source. However, consumption of eggs is often considered as responsible for some health problems due to high cholesterol content leading to coronary heart disease (BRAGAGNALO & RODRIGUEZ-AMAYA 2003). The authors compared the cholesterol content of Brazilian chicken and quail eggs. They showed that there was no significant difference in cholesterol level between chicken and quail eggs in terms of yolk (12.0 vs. 12.1 mg/g). Opposite results were presented by SINANOGLOU *et al.* (2011), who reported higher cholesterol content in quail egg yolk (13.6 mg/g) compared to BRAGAGNALO & RODRIGUEZ-AMAYA (2003). It should be emphasized that selection for cholesterol level in eggs of Japanese quail influences the physical traits of eggs. NOWACZEWSKI *et al.* (2010b) reported that eggs obtained from quails selected for low cholesterol content in yolk were characterized by poor quality of shell and albumen.

Table 3

Fatty acid profile of poultry eggs (HORBANCZUK *et al.* 1998; NOWACZEWSKI *et al.* 2013; POLAT *et al.* 2013)

Fatty acids	Species							
	Quail	Chicken	Goose	Duck	Turkey	Guinea fowl	Ostrich	Pheasant
16:0	22.8	21.1	25.1	24.4	22.1	22.8	23.9	26.0
16:1	4.65	5.02	4.60	3.95	6.54	6.45	5.71	7.48
18:0	5.53	7.44	8.07	6.21	4.38	4.16	6.43	4.36
18:1	39.9	33.9	47.2	48.3	40.4	40.3	39.7	43.3
18:2	22.2	28.5	10.7	12.5	21.5	22.0	20.4	16.0
18:3	0.44	0.95	0.16	0.50	0.31	0.71	0.88	0.67
20:4	1.9	1.3	1.8	1.4	1.9	1.55	1.32	1.01
20:5	0.08	0.09	0.01	0.2	0	0.04	0.24	***
22:5	0.16	0.1	0.29	0.06	0.25	0.11	***	***
22:6	0.22	0.31	0.58	0.12	0.19	0.13	0.84	***
SFA	29.9	29.7	34.2	31.2	28.3	28.4	30.3	34.1
MUFA	45.0	39.1	52.0	52.5	47.5	47.0	45.4	48.0
PUFA	25.1	31.3	13.8	15.7	24.3	24.6	23.7	17.9

*** not estimated; SFA – saturated fatty acid; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids.

DA SILVA *et al.* (2009) conducted research on the cholesterol levels in egg yolk of quail fed diets with four different amounts of flaxseed. No differences were found between the cholesterol levels of the four treatments. This result suggests that a diet rich in n-3 fatty acids does not affect the level of cholesterol in eggs, which is accordance with the results of COBOS *et al.* (1995). The opposite was reported by ATAKISI *et al.* (2009), who determined the effect of fish oil, rich in n-3 fatty acids, on cholesterol levels in egg yolk and plasma of Japanese quails. It was found that fish oil supplementation, which is rich in n-3 fatty acids, decreased the level of cholesterol in egg yolk and plasma in quails.

POLAT *et al.* (2013) determined the fatty acid composition of yolk of several poultry species kept in their natural environment, inter alia quail eggs (Table 2). They reported that quail eggs have a higher concentration of monounsaturated fatty acid in yolk (45%) compared to chicken eggs (39.1%) and lower content of polyunsaturated fatty acid (25.1% vs. 31.3%, respectively). The total concentration of saturated fatty acid in yolk was similar in both species.

Moreover, it should be noted that linoleic acid (LA; 18:2 n-6) and alpha-linolenic (ALA; 18:3 n-3) and their long chain derivatives (EPA; eicosapentaenoic acid; 20:5 n-3 and DHA; docosahexaenoic acid; 22:6 n-3) are important components of animal and plant cell membranes (SIMOPOULOS *et al.* 2000). Fish is one of the best sources of n-3 PUFA in the human diet, as it is rich in EPA and DHA fatty acids, whereas oil seeds, particularly linseed, have a high content (50-55%) of LNA (CHEN *et al.* 1994). The addition of n-3 fatty acids causes a qualitative change in the yolk fatty acid profile, reducing the n-6/n-3 ratio to a more favorable level in relation to human nutritional needs (SIMOPOULOS 1998).

DA SILVA *et al.* (2009) experimented with different levels of flaxseed and demonstrated that the n-6/n-3 ratio decreased from 21 (control group) to 4.5 in the 5% group, which is a more favourable value from the nutritional viewpoint. Flaxseed supplementation increased the ALA and DHA content in the 5% group as well (DA SILVA *et al.* 2009).

In turn, GENCHEV (2012) investigated the fatty acid content of the egg lipid fraction (Table 4) of two Japanese quail breeds – Pharaoh (Ph) and Manchurian Golden (MG) and observed no differences between quail breeds. The Pharaoh breed has a higher content of total saturated fatty acids in both lipid fractions (38.8 and 45.8%) compared to Manchurian Golden breed (36.9 and 43.9%). In turn, the latter had a higher content of monounsaturated and n-3 fatty acids in the phospholipid fraction (33 and 1.4%, respectively) but lower n-6/n-3 fatty acids ratio (15.9) compared to the Pharaoh breed.

Table 4

Fatty acid content (%) of egg lipid fraction in quail (GENCHEV 2012)

Fatty acid	Triglycerides		Phospholipids	
	Ph	MG	Ph	MG
∑ n-6	9.3	9.6	22.6	21.8
∑ n-3	0.2	0.2	1.2	1.4
n-6/n-3	42.5	41.6	18.9	15.9
∑ MUFA	51.3	52.9	30.7	33.0
∑ SFA	38.8	36.9	45.4	43.9
∑ PUFA	9.9	10.2	23.8	23.1
PUFA/SFA	0.26	0.28	0.53	0.53

Ph – Pharaoh Japanese quail, MG – Manchurian Golden Japanese quail; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; SFA – saturated fatty acid; PUFA/SFA – polyunsaturated/saturated ratio.

Amino acids

One of the most important factors determining the quality of food protein is amino acid composition. In general, high protein food is also high in contents of amino acids including eight which are essential in human nutrition: lysine, valine, leucine, isoleucine, threonine, tryptophan, methionine and phenyloalanine (NEDKOV 2004; KIM *et al*. 2009).

Analysis of amino acids in eggs of two Japanese quail breeds, Pharaoh and Manchurian Golden, reveals a high content of essential amino acids in eggs – 50.4% of albumen protein and 48.6% of yolk protein. From essential amino acids, the content of leucine and lysine was the highest: 16.3% of albumen protein and 18% of yolk protein (GENCHEV 2012). The ratio between essential and nonessential amino acids was nearly 1 (Table 5). The concentration of essential amino acids in yolk from chicken eggs is lower (7.04 %) compared to yolk from Manchurian Golden and Pharaoh quail eggs (7.54 and 7.71%, respectively). The content of the essential amino acid leucine was the highest (1.37%) in yolk of chicken eggs, comparable to the concentration of this amino acid in yolk of quail eggs (1.4%). Yolk from chicken eggs is richer in valine (1.12%) compared to yolk of quail eggs (0.95%, GENCHEV 2012).

Table 5

Amino acid content (%) of quail eggs (GENCHEV 2012)

Amino acid	Yolk and albumen		Albumen		Yolk	
	Ph	MG	Ph	MG	Ph	MG
Aspartic acid	1.3	1.29	1.26	1.21	1.38	1.42
Threonine	0.73	0.73	0.67	0.64	0.84	0.86
Serine	0.94	0.92	0.78	0.74	1.23	1.26
Glutamic acid	2.06	2.02	2.08	1.98	2.05	2.10
Proline	0.64	0.64	0.58	0.55	0.75	0.77
Cysteine	0.57	0.55	0.66	0.63	0.4	0.41
Glycine	0.44	0.44	0.45	0.43	0.42	0.43
Alanine	0.72	0.72	0.71	0.68	0.75	0.77
Valine	0.90	0.89	0.88	0.84	0.94	0.97
Methionine	0.44	0.43	0.40	0.38	0.51	0.52
Isoleucine	0.65	0.65	0.58	0.55	0.79	0.81
Leucine	1.24	1.23	1.15	1.10	1.42	1.45
Thyrosine	0.52	0.51	0.49	0.47	0.56	0.57
Phenyloalanine	0.78	0.76	0.82	0.78	0.71	0.72
Histidine	0.48	0.48	1.07	0.37	0.64	0.65
Lysine	1.18	1.17	0.37	1.03	1.37	1.40
Arginine	0.49	0.48	6.72	0.35	0.7	0.71
∑ EAA	7.01	6.92	6.72	6.42	7.54	7.71
∑ NAA	7.07	6.99	6.62	6.31	7.92	8.01
EAA:NAA	1:0.99	1:0.99	1:1.015	1:1.017	1:0.95	1:0.96

Ph – Pharaoh Japanese quail, MG – Manchurian Golden Japanese quail; EAA – essential amino acid; NAA – nonessential amino acid; EAA:NAA – essential amino acid and nonessential amino acid ratio.

Biologically important proteins are also derived from eggs. One of these proteins is avidin (0.05% of the total protein content of egg albumen). Avidin is an alkaline, highly stable, homotetrameric protein, binding up to four molecules of D-biotin with extremely high affinity. Therefore, people should not consume large quantities of raw eggs because this can result in a deficiency of biotin which may have an effect on human health such as increasing the cholesterol level in blood (KOVACS-NOLAN *et al.* 2005; NAU *et al*. 2007). On the other hand, some findings show a potential use of avidin from egg albumen to reinforce some anticancer treatments (GASPARRI *et al.* 1999). Lysozyme is also a very important protein in the egg albumen. It is characterized by high enzymatic activity against bacteria and fungi (SALTON & PAVILIK in ŚWIERCZEWSKA *et al*. 1998). There is a lack of information on lysozyme content in quail eggs in the poultry literature. However, based on our study, the concentration and activity of the enzyme in liquid albumen of Japanese quail eggs is 0.215% and 38100 U/ml, respectively (unpublished data). These values were found to be higher (0.260% and 56059 U/ml) in pheasant eggs (NOWACZEWSKI *et al.* 2013). Higher activity of lysozyme (70483 U/ml) was also noted in goose eggs (ROSIŃSKI 2000). On the other hand, ducks (different conservation flocks) were characterized by lower concentration and activity of the enzyme in eggs (0.147% and 31518 U/ml) in comparison with quails (LEWKO & GORNOWICZ 2012).

Mineral and vitamin composition

The mineral composition of the different parts of quail eggs is presented in Table 6. The albumen was the richest in P (37% of total mineral), Ca (31%) and Mg (31%). Yolk is a main source of P (74%) and Ca (23%) which are important in human nutrition and should be consumed irrespective of high cholesterol content. Yolk of quail eggs

Table 6

Mineral content (mg/kg) of quail eggs (GENCHEV 2012)

Mineral	Yolk	Albumen
Ca	1490	85
P	4880	100
Mg	111.41	83.25
Fe	39.39	0.45
Cu	0.62	0.45
Zn	18.98	1.37

is richer in Ca compared to yolk from chicken eggs (1184 mg/kg) but poorer in P, Mg and Zn than yolk from chicken eggs in which the levels of these macro- and microelements are c. 5120, 209, and 46 mg/kg, respectively (GENCHEV 2012).

In an analysis of internal egg components, SHANAWAY (1994) found that quail eggs are characterized by higher content of P (220 vs. 181 mg/100g) and Fe (3.8 vs. 2.4 mg/100g) than chicken eggs. A comparative study assessing metal content in eggs of different species of birds (ABDULJALEEL *et al*. 2011) found a higher level of Mn, Co, Zn and Cu in quail eggshells in comparison with chicken and Guinea fowl. On the other hand, the eggshells of chicken and Guinea fowl had higher content of Se, As and Fe. The difference was particularly evident in the level of iron and amounted to almost 50%. It should be emphasized that quail eggshells are richer in As and Co. The content of Mn, Fe, Co, Zn and Cu (2.96, 183.50, 0.48, 48.47 and 4.67 μg/g dry weight, respectively) was highest in quail egg (ABDULJALEEL *et al*. 2011). In the case of selenium, its concentration in quail eggs can differ significantly. As described by GRAVENA *et al.* (2011), increasing organic Se content in bird diet results in elevated levels of this microelement in egg albumen. SZABLEWSKI *et al.* (2013) reported that the mineral composition of chicken eggs can depend on bird origin. For example, significantly higher levels of Na, K, Ca and Fe in egg liquid were found in Rhode Island Red than Sussex hens.

There is not much information in the literature about vitamin concentration in Japanese quail eggs (Table 7). The average content of vitamins A, D and E in quail egg is 7.2, 0.011 and 59.2 μg/g. SAHIN *et al*. (2006) determined the effect of dietary supplementation with vitamin E, lycopene and their combination on egg production and egg quality of quails including concentrations of vitamins E and A. They showed that birds fed a basal diet contained 55.00 and 5.19 μg/g of yolk vitamins E and A, respectively. Dietary supplementation with vitamin E and lycopene significantly increased the level of vitamin E (162.00 and 72.20 μµg/g of yolk) and vitamin A (5.66 and 5.54 μg/g of yolk) compared to the control group.

Table 7

Content of some vitamins in quail eggs (WHITING 1966; TUNSARINGKARN *et al.* 2013)

Vitamin	Concentration
A (μg/g)	7.17
D (μg/g)	0.011
E (μg/g)	59.20
Thiamine – B1 (mg/100g WLE*)	0.12
Riboflavin – B2 (mg/100g WLE*)	0.85
Niacin – B3 (mg/100g WLE*)	0.10

*WLE – Whole Liquid Egg.

Conclusion

Quail eggs are gaining popularity because of their unique colour and mottles, and are favoured by consumers, especially during Easter. However, as a high quality product, it may be a valuable supplement of the human diet. Quail eggs have lower fat content as compared to chicken eggs, however the cholesterol levels are similar. It is worth emphasizing that quail eggs are richer than chicken eggs in essential amino acids and minerals such as Ca, P and Fe.

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