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Original Contribution

QUALITY AND COMPOSITION OF JAPANESE QUAIL EGGS *(COTURNIX JAPONICA)*

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ABSTRACT
The quality traits and the composition of Japanese quail eggs in relation to layers' age were investigated. During the entire 7-month period, a total of 1,762 eggs from the Pharaoh breed (Ph) and 1,858 eggs from the Manchurian Golden breed (MG) were studied.
The weight of Japanese quail eggs changed most consistently during the first 3 months of the production cycle (P<0.001). Subsequently, during the first 3 months, the shape of eggs became more elongated. Throughout the cycle, the quality traits of egg albumen, yolk and eggshell gradually decreased and attained lowest values by the end of egg laying (P<0.001). The mean Haugh units and IQU values were respectively 89.04±0.131 and 56.08±0.291 (Ph); 88.99±0.142 and 56.26±0.314 (MG).
The yolk index varied between 0.234 and 0.577, with most stable quality between production months 3 and 5. During the major part of the cycle, Ph quail eggs were with thicker eggshells – 213.77±0.527 µm vs. 202.01±0.555 µm in MG (P<0.001).
The essential amino acid content of Japanese quail eggs comprised 50.36% of albumen protein and 48.65 % of yolk protein. The PUFA content in the phospholipids fraction of the yolk was almost 2.5 times higher than in the triglyceride fraction, whereas the PUFA:SFA ratio was 0.52:1 vs. 0.26:1-0.28:1 in the triglyceride fraction. Out of albumen mineral substances, the highest content was that of phosphorus, calcium and magnesium. The yolk was the richest in phosphorus and calcium, whereas the eggshell – in calcium.

Key words: Japanese quails, egg quality, egg composition

The issues related to the quality and compositions of eggs produced by domestic fowl are of primary importance. They have received a considerable attention since the middle of 19th century. The most detailed review on the subject was however published in 1949 by Romanoff and Romanoff in their fundamental research work „The Avian Egg", which turned out to be a kind of a Bible of the poultry industry (1).

Most numerous and detailed investigations in both world and national scientific literature have been performed on chicken egg quality and composition (2, 3, 4). During the last two decades, the scope of research included other fowl species of fewer economic significance for conditions in Bulgaria: turkeys (5) Muscovy ducks (6), guinea fowl (7), Japanese quails (8, 9), ostriches (10) etc.

Egg quality is usually commented in connection with consumers' requirements and is performed by groups of methods, which give a general characteristics of egg with intact eggshell (freshness, weight, size and shape, eggshell appearance) and the quality of egg parts (albumen, yolk and eggshell).

From the point of view of consumers, egg weight is the most quality trait. In Japanese quails, this trait is related to sexual maturity (11), production type (12), the stage of production cycle (13), housing density (14) etc. Another important exterior trait is the eggshell integrity. According to the extent of its damage, eggs could be divided into three groups – with broken external and internal cracks. Eggshell integrity is important not only

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from economic point of view, but also with regard to human health safety.

The evaluation of the quality of egg parts is performed after breaking. The average weight of albumen of quail eggs ranges between 4.9-5.0 g (15), i.e. about 53.5-59.5% of the total egg weight (12). Albumen index of fresh quail eggs is between 0.1 and 0.15 (16, 17).

Quail egg yolk weighs about 4.3-4.5 g (15), and largely determines the nutritive value of the egg as a whole. The relative proportion of yolk is 31-37% of egg's weight (12). The yolk index of fresh eggs varies within 0.48-0.52, with a tendency towards increase up to 0.53-0.54 with layers' age (17).

The most important quality traits of the eggshell are its strength and thickness. The thickness of quail eggs with membranes varies from 0.191 (8) to 0.219 mm (17). As the age of layers advances, resp. the production cycle stage, Gonzalez (17) established a stable trend towards reduction of shell thickness, while Nikolova and Penkov (9) reported that it was the thinnest by the beginning of egg laying.

The few and inconsistent reports on the quality and the composition of quail eggs in the national literature motivated the present study. It aimed to investigate the quality traits of Japanese quail eggs depending on the age of layers and to provide more detailed information about their composition.

MATERIAL AND METHODS

A detailed study of egg quality in two Japanese quail breeds – Pharaoh (Ph) and Manchurian Golden (MG) was carried out. The evaluation of quality of eggs was done since the beginning of egg laying and continued over the next 7 production months. By the middle of each month, all eggs laid within a 24-hour period were collected for quality analysis. The eggs were weighed, measured and broken the same day. During the production period, a total of 1,762 Ph eggs and 1,858 MG eggs were analysed.

Weight and metric analysis. The weight of eggs and their parts – albumen, yolk and eggshell with membranes were determined with a precision of 0.01 g on *CB2000* analytical balance.

During the experiment, the following parameters were controlled: egg weight, shape index, yolk index, albumen index, Haugh units, internal quality units (IQU) and shell thickness.

The long and short axes of eggs were measured by means of a technical calliper with a precision of 0.05 mm. The diameters of egg albumen and yolk were determined after breaking the egg on a horizontal smooth surface. The yolk and albumen heights were determined with a tripod AMES micrometer with a precision of 0.01 mm. The eggshell thickness together with shell membrane was measured with a special AMES micrometre in the equatorial region and both poles (sharp and blunt). The arithmetic mean of the three measurements was retained as eggshell thickness.

Metric parameters. On the basis of egg exterior dimensions, shape index (SI, %) was determined by the formula $SI=d/D*100$ where d is the short axis, D – the long axis of the egg (1). Egg volume (cm^3) was calculated by the equation $EV=4/3*\pi*(D/2)*(d/2)^2$, where d is the short axis (cm), D: the long axis (cm), and π= 3.14159 (18). The eggshell surface was calculated as $SSA=4.835*EW^{0.662}$, where EW is the egg weight (19). To determine the quality traits of albumen, the following parameters were calculated:

The albumen index: $AI=h/((0.5*(D+d))$, where h is the height of thick albumen at the boundary with the yolk; d and D – the long and short diameters of albumen measured on the smooth surface (1).

Haugh units: $HU=100*log(h+7.57-1.7*EW^{0.37})$, where h is the height of thick albumen at the boundary with the yolk; EW – the egg weight (20).

Internal quality units: IQU= $100*log(h+4.18-0.89897*EW^{0.6674})$, where h is the height of thick albumen at the boundary with the yolk; EW – the egg weight (21).

Yolk quality was evaluated through the yolk index: $YI= h/D$, where h is the yolk height and D – the yolk diameter (1).

Laboratory analyses. During the third and the fifth production months, average samples of egg albumen, yolk and eggshell were collected for complete chemical analysis in the accredited research lab of the Faculty of Agriculture. The analysis of total protein, water, fat and mineral contents were performed by the classical method of chemical analysis (22). The amino acid content was determined following acid hydrolysis of samples with 6 N HCl at 110 °C for 24 h, and amino acid separation was done with an *amino acid analyzer T339M* (Mikrotechna – Praha). Mineral content in albumen, yolk and eggshell samples was assayed after dry ashing of samples at 550°C and dissolution in hydrochloric acid. The calcium content in eggshell was determined by permanganate titration and that of phosphorus – by the molybdate/vanadate method. The other elements, including calcium content in albumen and yolk, were assayed on an atomic absorption spectrophotometer Analist 800, *Perkin Elmer*.

The lipid and fatty acid composition of the yolk was determined by fat extraction with methanol: chloroform (2:1) by the method of Bligh and Dyer (23) followed by thin-layer chromatography and fatty acid separation on a gas chromatograph *Pay Unicam* 304 equipped with flame ionisation detector and a capillary column EC™ WAX (*Alltech*, 30 m x 0.25 mm, i.d., 0.25 µm film), using H_2 as a carrier gas.

The total cholesterol content was assayed colorimetrically by the Schoenheimer-Sperry method, modified by Sperry and Webb (24).

Statistical analysis. The data were statistically analysed by classic methods of statistical analysis using *MS Excel 2003*.

RESULTS

During the experimental period, egg weight was the most consistently changing trait **(Fig. 1)**. In Ph quails, it increased up to the 3rd month, whereas in MG quails – up to the 4th month. IN both breeds, the most dynamic changes occurred until the 3rd month, when the differences were statistically significant (P<0.001). After that, the tendency was towards a decline with more fluctuations in the MG quail breed. The egg weight was higher in Ph quails for the entire period, with average value 13.71±0.022 vs. 13.25±0.029 for MG (P<0.001). The other exterior traits of eggs: long and short axis, volume and eggshell surface **(Table 1)** changed correspondingly. Here again, the changes during the first three production months were more pronounced – the long egg axis increased by 3.8-4.3%, the short axis by 2.8%, the egg volume by 8.9-9.3% and eggshell surface by 6.2-6.3%. The more intensive increase in long axis reflected upon the lower shape index percentages by 1.1% (P<0.001) in Ph quails and 1.9% (P<0.01) in MG quails **(Fig. 2)**. After the 4th month, the egg shape index in both studied breeds ranged within 76.8-77.4%. The average values during the controlled period were 77.36±0.084% (Ph) vs. 77.14±0.088% (MG), the difference of 0.3% was insignificant.

The traits indicative of albumen quality in this study ranged within a wide range – albumen height between 2 and 8.4 mm, albumen index between 0.037 and 0.181, Haugh units – within 72.3-106.51, and IQU – between 15.74 and 88.52. The highest values of these traits were recorded by the beginning of egg laying **(Table 2).** During the first two months of production, the values in the Ph breed were higher than the average ones by 5.3-11.2% for albumen height, 11.9-13.9% for albumen index, 2.1-3.1% for Haugh units and 8.8-10.3% for IQU. In Manchurian Golden quails, the highest values were those of the first production month, which were higher than the average by 8.3% (albumen height), 19% (albumen index), 3% (Haugh units) and 2.4% (IQU). As the production cycle advanced, the values of studied traits gradually decreased and were the lowest by its end (P<0.001).

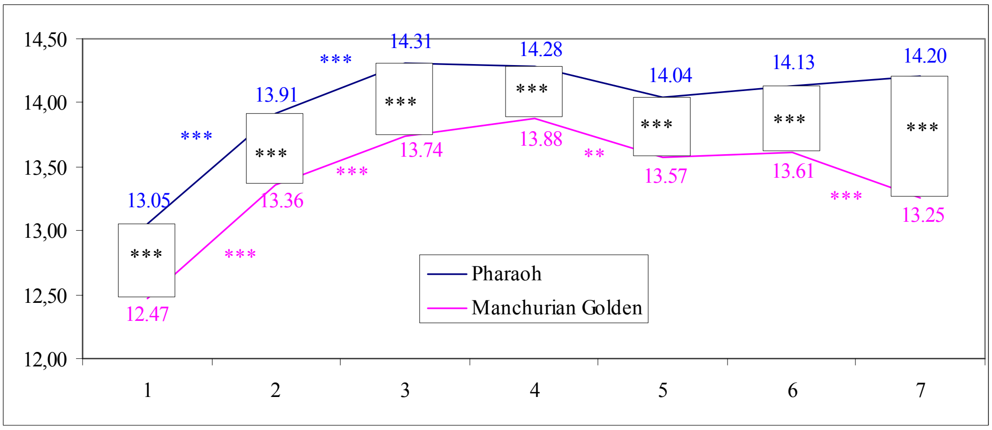

Fig. 1. Weight of Japanese quail eggs, g.

Table1. . *Exterior traits of eggs*

Production month	Long axis , mm		Short axis, mm		Egg volume, cm^3		Eggshell surface, cm^2	
	Pharaoh	MG	Pharaoh	MG	Pharaoh	MG	Pharaoh	MG
1	34.05±0.075^{d}	33.53±0.169^{d}	26.49±0.043^{d}	26.14±0.095^{de}	12.54±0.058^{d}	12.06±0.115c	26.37±0.083^{c}	25.63±0.165^{e}
significance	**		***		***		***	
2	35.07±0.069^{ac}	34.53±0.105^{c}	27.06±0.037^{bc}	26.77±0.054^{c}	13.46±0.052^{bc}	12.99±0.080^{ae}	27.68±0.073^{d}	26.76±0.158^{bd}
significance	***		***		***		***	
3	35.40±0.089^{bc}	35.07±0.104^{e}	27.23±0.052^{ac}	26.89±0.043^{c}	13.76±0.071^{e}	13.30±0.077^{bd}	28.10±0.097^{e}	27.36±0.148^{a}
significance	*		***		***		***	
4	35.40±0.102^{bc}	35.23±0.105^{be}	27.22±0.058^{ac}	27.02±0.051^{bc}	13.76±0.083^{e}	13.49±0.077^{d}	28.09±0.114^{e}	27.73±0.108^{c}
significance	ns		**		*		*	
5	35.17±0.136^{ac}	34.79±0.113^{a}	27.16±0.069^{ac}	26.77±0.058^{a}	13.62±0.107^{ce}	13.08±0.087^{ae}	27.88±0.148^{e}	27.15±0.122^{d}
significance	*		***		***		***	
6	35.29±0.122^{ac}	34.79±0.113^{a}	27.21±0.060^{ac}	26.84±0.061^{a}	13.71±0.094^{ae}	13.14±0.085^{b}	28.02±0.130^{e}	27.23±0.118^{ad}
significance	**		***		***		***	
7	35.27±0.122^{ac}	34.60±0.108^{af}	27.26±0.056^{ac}	26.59±0.064^{be}	13.75±0.091^{ae}	12.83±0.083^{ae}	28.07±0.126^{e}	26.81±0.115^{bd}
significance	***		***		***		***	
Average	34.96±0.041	34.76±0.044	27.01±0.041	26.78±0.023	13.34±0.035	13.07±0.033	27.50±0.049	27.14±0.047
significance	***		***		***		***	

Means with a column with different superscripts are significantly different (a,b P<0.01; c,d,e,f – P<0.001).

Table 2. *Egg albumen quality*

Production month	Albumen height, mm		Albumen index		Haugh units		IQU	
	Pharaoh	MG	Pharaoh	MG	Pharaoh	MG	Pharaoh	MG
1	4.97±0.048^{d}	5.00±0.113^{ad}	0.119±0.001^{c}	0.124±0.003^{c}	90.88±0.260^{c}	91.66±0.589^{c}	61.01±0.549^{ac}	63.25±1.159^{c}
significance	ns		ns		ns		ns	
2	5.24±0.055^{c}	4.65±0.070^{bd}	0.121±0.002^{c}	0.106±0.002^{d}	91.82±0.282^{ac}	89.25±0.374^{d}	63.16±0.825^{ac}	57.23±0.802^{d}
significance	***		***		***		***	
3	4.61±0.080^{d}	4.71±0.071^{bd}	0.103±0.002d	0.105±0.002^{d}	88.05±0.445^{b}	89.23±0.386^{d}	53.07±1.030^{bc}	56.42±0.848^{d}
significance	ns		ns		*		*	
4	4.58±0.070^{d}	4.59±0.067^{bd}	0.102±0.002^{d}	0.104±0.002^{d}	87.94±0.382^{d}	88.48±0.365^{d}	52.99±0.864^{bc}	54.63±0.798d
significance	ns		ns		ns		ns	
5	4.64±0.081^{d}	4.61±0.073^{bd}	0.102±0.002^{d}	0.107±0.002^{d}	88.44±0.442^{d}	88.83±0.416^{d}	54.50±0.994^{bc}	55.80±0.970^{d}
significance	ns		ns		ns		ns	
6	4.68±0.071^{d}	4.70±0.057^{bd}	0.104±0.002^{d}	0.102±0.002^{d}	88.78±0.405^{d}	89.33±0.298^{d}	55.40±0.947^{bc}	56.97±0.634^{d}
significance	ns		ns		ns		ns	
7	4.23±0.066^{e}	4.17±0.070^{c}	0.091±0.002^{e}	0.089±0.002^{e}	85.98±0.411^{e}	86.44±0.403^{e}	48.84±1.030^{d}	50.96±0.968^{e}
significance	ns		ns		ns		ns	
Average	**4.72±0.023**	**4.62±0.028**	**0.106±0.001**	**0.105±0.001**	**89.04±0.131**	**88.99±0.142**	**56.08±0.291**	**56.26±0.314**
significance	**		ns		ns		ns	

Means with a column with different superscripts are significantly different (a,b P<0.01; c,d,e,f – P<0.001).

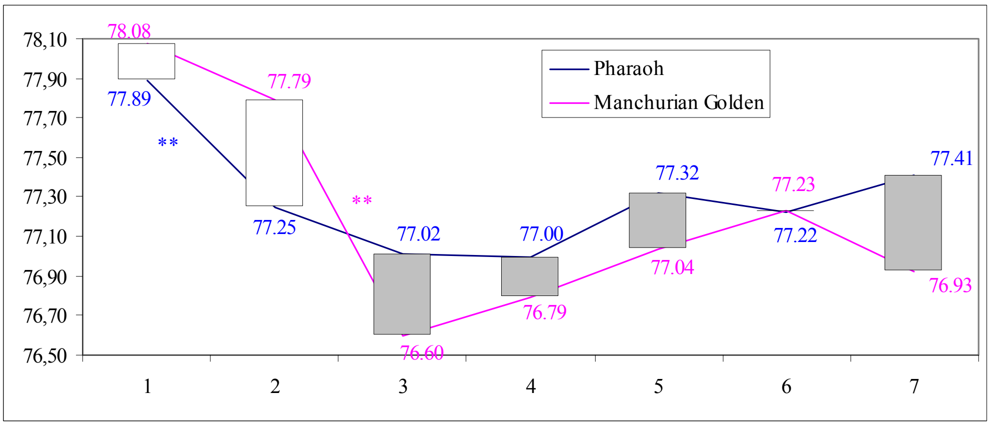

Fig. 2. Egg shape index of Japanese quail eggs, %

Yolk quality, similarly to that of albumen, was superior by the beginning of the cycle **(Fig. 3).** In both breeds, the yolk index varied between 0.234 and 0.577, with average values for the entire cycle of 0.454±0.001 for Ph vs 0.447±0.001 for MG. The difference of 1.6% was statistically significant (P<0.001). The yolk quality was relatively most stable between the 3rd and the 5th production months.

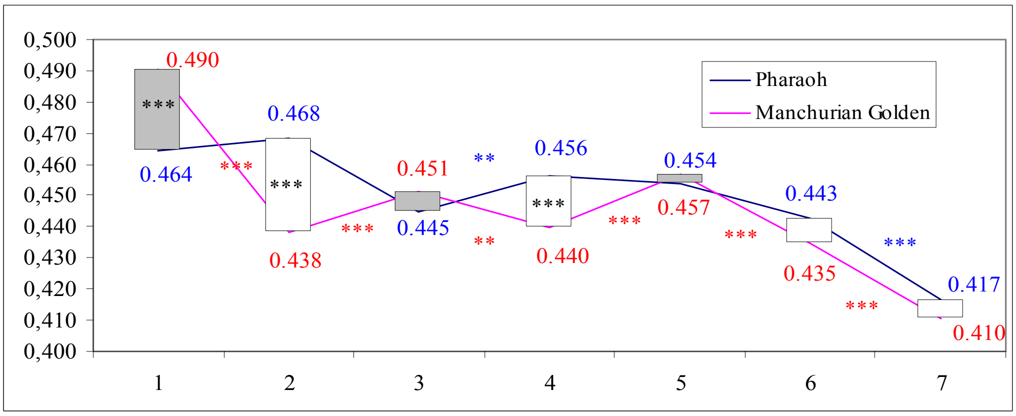

Fig. 3. Yolk index of Japanese quail eggs.

The eggshell thickness in studied Japanese quail breeds varied within 130-280 µm, with highest values during the first month **(Fig. 4).** The highest interbreed difference was observed during the first two months –7.7-7.3% (P<0.001). In the course of the cycle, eggshell thickness decreased as did the egg quality parameters, being more pronounced by the end of egg laying. If both breeds are compared, during the major part of the cycle Ph quails had thicker eggshells – 213.77±0.527 µm vs. 202.01±0.555 µm in MG quails (P<0.001).

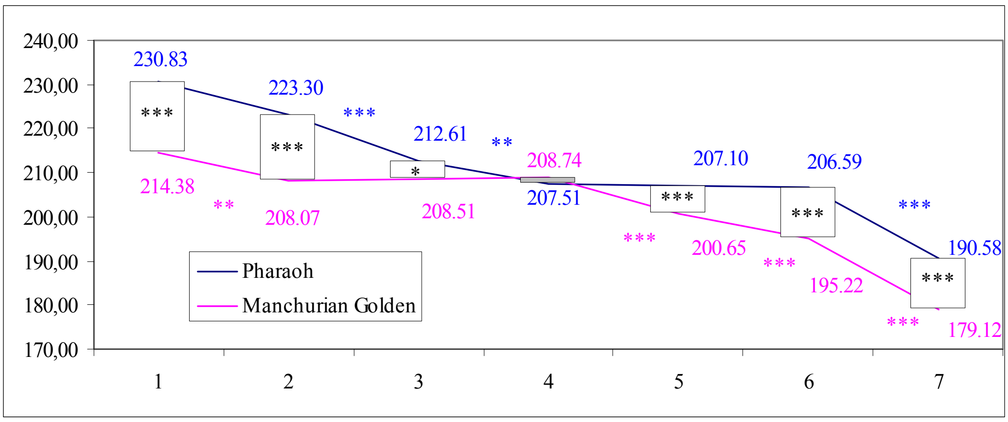

Fig. 4. Eggshell thickness, µm

Investigating the structure of the quail egg, it was established that albumen weight varied between 5.7 and 11 g, consisting 50-65.5% of egg weight (average 59.23±0.083) in Ph and 55.4-67.9% in MG quails (60.13±0.078 in average) (P<0.001). Yolk weight varied between 3 and 6.2 g, corresponding to 25.4-36.3% (average 31.94±0.066) of total egg weight in Ph and 24.4-36.6% (average 31.80±0.070) in MG quails. The difference of 0.4% was not statistically significant. The biggest variations were observed for eggshell weight – from 0.6 to 1.8 g. It relative proportion vs. egg weight was between 5.5 and 11.6% (8.17±0.018) in Ph and 5.8-10.6% (8.03±0.019) in MG quails (P<0.001). The time course of changes in egg parts showed statistically significant differences between the first and the seventh production month **(Fig. 5;** P<0.001). The albumen weight was increased by 3.1% and 3.8% in Ph and MG, respectively. The relative proportion of yolk and eggshell decreased with greater difference in the proportion of the eggshell – 6.0% in Ph and 8.6% in MG breeds. In both quail breeds, the share of the yolk decreased by about 4%.

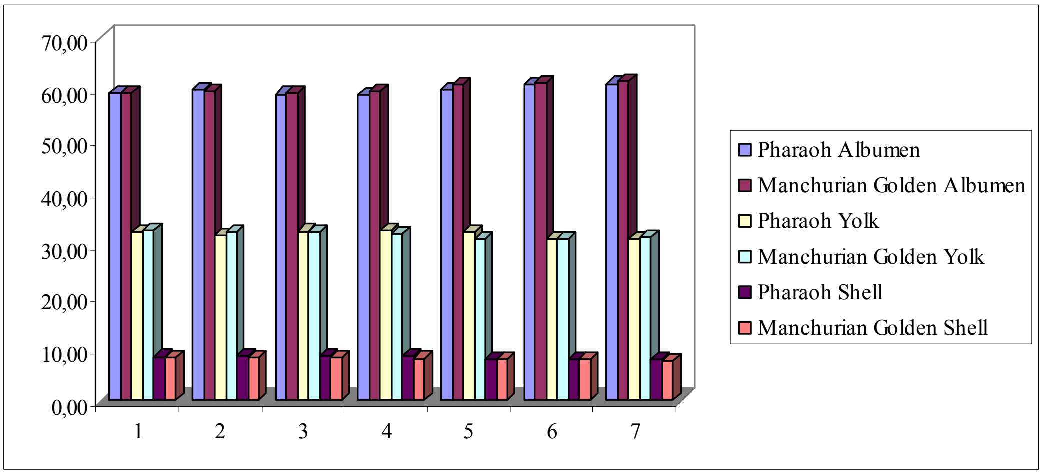

Fig. 5. Relative proportions of egg parts, %

With regard to egg composition, there were not any significant inter-breed differences **(Tables 3 and 4).** It was interesting to note the high content of essential amino acids in Japanese quail eggs – 50.36% of albumen protein and 48.65 % of yolk protein. Out of essential amino acids, the sum of leucine and lysine was the highest: 16.63% of albumen protein and 17.97% of yolk protein. The ratio between essential and nonessential amino acids was almost 1.

Table 3. *Chemical composition of Japanese quail eggs*

Parameter	Yolk and albumen		Albumen		Yolk	
	Pharaoh	MG	Pharaoh	MG	Pharaoh	MG
Weight, g	12.81	12.54	8.32	8.2	4.49	4.34
Dry matter, %	26.72	26.06	14.60	14.06	50.6	50.87
Crude protein, %	14.08	13.91	13.34	12.73	15.46	15.82
Crude fat, %	11.15	10.65	0.2	0.2	33.47	33.09
Including: triglycerides					61.9	62.4
phopholipids					33.02	33.40
total cholesterol					4.76	4.12
Ash, %	0.98	0.89	0.76	0.78	1.12	1.36

The analysis of fatty acid content of lipids demonstrated that the phospholipid fraction of the yolk was almost 2.4 times richer in PUFA compared to the triglyceride fraction, whereas the ratio of PUFA:SFA was 0.52:1 vs. 0.26:1 – 0.28:1 in triglycerides **(Table 5)**. The proportion of palmitic acid (C16:0) was the highest among SFA, and that of oleic acid (C18:1) – among MUFA. Among PUFA, the linoleic acid (C18:2) content was the highest with content in the phospholipid fraction by 52-71% higher than that in triglycerides. The precursors of Ώ6 and Ώ3 fatty acids – linoleic and α-linolenic acids, were detected only in triglyceride fraction whereas the other Ώ6 (arachidonic, docosapentaenoic) and Ώ3 (eicosapentaenoic and docosahexaenoic) acids were found out in the phospholipid fraction only.

Table 4. *Amino acid content of eggs, %*

Amino acid	Yolk and albumen		Albumen		Yolk	
	Pharaoh	MG	Pharaoh	Pharaoh	MG	Pharaoh
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
Phenylalanine	0.78	0.76	0.82	0.78	0.71	0.72
Histidine	0.48	0.48	0.39	0.37	0.64	0.65
Lysine	1.18	1.17	1.07	1.03	1.37	1.40
Arginine	0.49	0.48	0.37	0.35	0.7	0.71
Σ essential amino acids	7.01	6.92	6.72	6.42	7.54	7.71
Σ nonessential amino acids	7.07	6.99	6.62	6.31	7.92	8.01
Essential : nonessential	1 : 0.99	1 : 0.99	1 : 1.015	1 : 1.017	1 : 0.95	1 : 0.96

Table 5. *Fatty acid content of egg lipid fractions, % of lipid fraction*

Fatty acid	Triglycerides		Phospholipids	
	Pharaoh	MG	Pharaoh	MG
Myristic (C14:0)	0.8	0.86	0.41	0.34
Palmitic (C16:0)	31.51	30.09	32.18	27.36
Palmitoleic (C16:1)	7.23	7.75	3.85	2.92
Stearic (C18:0)	6.46	5.94	12.85	16.22
Oleic (C18:1)	44.06	45.19	26.87	30.03
Ώ6 Linoleic (C18:2)	9.34	9.56	16	14.55
Ώ3 α Linolenic (C18:3)	0.22	0.23		
Σ CLA	0.38	0.38		
Ώ6 Arahidonic (C20:4)			6.64	7.21
Ώ3 Eicosapentaenoic (C22:5)			0.31	0.33
Ώ3 Docosahexaenoic (C22:6)			0.89	1.04
Σ SFA	38.77	36.89	45.44	43.92
Σ PUFA	9.94	10.17	23.84	23.13
PUFA/SFA	0.256	0.276	0.525	0.527

A more substantial inter-breed difference (15.5%) was found out in total cholesterol content – 1593.54 mg/100 g yolk and 1362.93 mg/100 g yolk in Ph and MG quails, respectively. These values made up 4.76 and 4.12% of total yolk lipids, respectively.

The mineral composition of the different parts of quail eggs is presented on **Fig. 6.** It could be seen that most prevailing macroelements in the albumen were phosphorus – 36%, calcium – 31 % and magnesium– 31%. The content of other trace elements was about 2%. The yolk was the richest in phosphorus – 74% and calcium – 23%. About 99% of eggshell content was attributed to calcium.

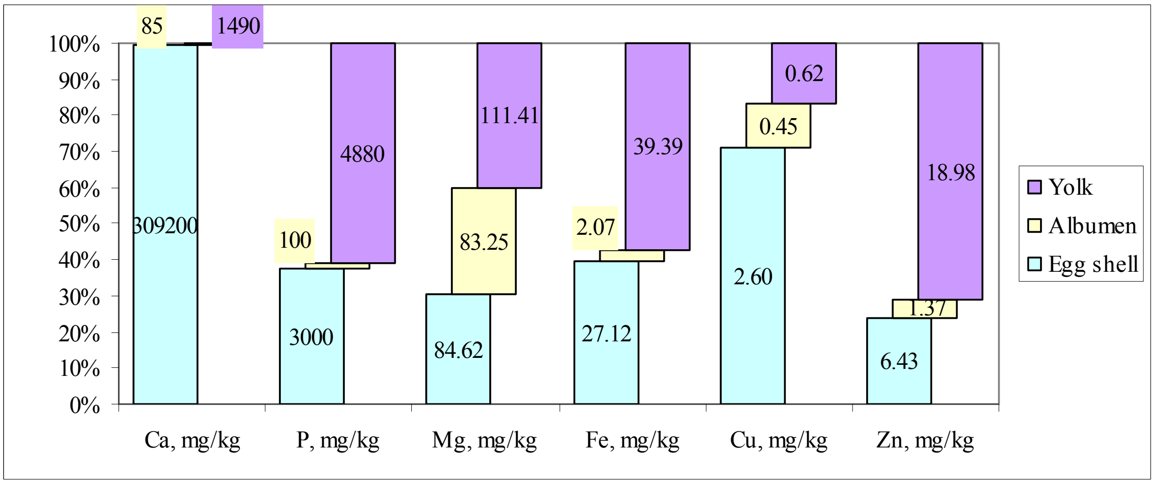

Fig. 6. Mineral contents of egg parts, mg/kg

DISCUSSION

Egg weight is among the most important parameters not only for consumers, but for egg producers as well. This is of particular concern when eggs are produced by small fowl species and when their weight is several times lower than that of a standard chicken egg (60-63 g). The leading rationale for both producers and consumers is the economic one. However, while from consumer's point of view the aim is to obtain as much product as possible for less money, the increase in weight for producers is justified only to a specific threshold (25). After attaining peak egg production and especially by the end of the laying cycle, the return on investment from sales of larger eggs does not compensate for the higher production costs. The average egg weight obtained in the present study was by 28.8-46.1% higher than reported data in egg-type quails – from 9.34 (8) to 10.6 g (17) and corresponded to data of Nikolova and Penkov (9) for the same breed – 13.65 g (12.93-14.32 g).

The shape of eggs changed at a lesser extent within the production cycle. According to this study, the shape index was the highest by the beginning of egg laying as also supported by other researchers (17). After the first production month, the shape of eggs was slightly elongated, which was largely due to the more intensive increase of long (3.6%) than the short egg axis (2.4-2.9%). On the contrary, Nikolova and Penkov (9) have reported that within a 10-week production period, the egg shape became more oval.

The albumen viscosity is the most important quality trait. Unfortunately, it could be assessed only indirectly by determining the albumen height and its surface area. The reduced albumen heights observed throughout the production cycle indicated a clear effect of this factor on albumen quality. The more intensive decrease in viscosity between production months 6 and 7 was due to ambient temperature (the study is performed by the end of June). A similar relationship to ambient temperatures was stated by Gonzalez (17), but the results indicated that the effect of layers' age was the most essential. The changes in the other quality traits: albumen index, Haugh units and internal quality units were in accordance with albumen height alterations. Albumen index range observed in this study was similar to the reports of other researchers, including for other domestic fowl species: – 0.099-0.138 for Japanese quail eggs (17), 0.068-0.077 for turkey eggs (5) and 0.09-0.115 for chicken eggs (4). The Haugh units, used frequently during the last decades to evaluate albumen quality ranged between 87.08 (26) and 103.1 for quail eggs (9). IQU, derived by modification of the classic equation of Haugh (20) logically followed a similar tendency. The specificity about this index is that the differences between various reports are more pronounced than those in Haugh units and therefore, more clearly identifiable. In this study, Haugh units by the end of the production cycle were 97-98.9% of values during the first production month, while IQU were 88.6-94.7%. In this connection, we agree with the opinion of Imai et al. (27) that IQU was a better parameter of quail eggs quality. According to the authors, IQU of fresh quail eggs is about 62. A similar value was published by Gonzalez – 61.3 (17). In our study, comparable values were obtained only during the first two months in the Pharaoh quail breed and during the first month in Manchurian Golden quails. Our average IQU values were by about 10% lower, most probably because of the greater variation of albumen height (CV 18.1-20.5%). This reflected in deviations from the mean value of the trait from -57.1% to +80.3%.

The most important criterion for evaluation of the nutritive value of quail eggs is their composition. The biological value of protein could be evaluated also by the ratio between essential amino acids. In 1957, FAO/WHO specialists assumed the concept about the "ideal protein" composed of essential amino acids, with minimum content of each amino acid. In 1973, the content of the different amino acids was revised and the following content was approved: lysine 5.5%, methionine+cysteine 3.5%, threonine 4%, leucine 7%, isoleucine 4%, valine 5%, phenylalanine+tyrosine 6% and tryptophan 1% (28). The content of essential amino acids in Japanese quail egg protein was 49.3-49.7%, with respective share of lysine and methionine+cysteine of 8.33% and 7.11%.

Apart protein, the intake of fat is exceptionally important for the healthy human diet. The lipids of quail eggs contain about 55.92% (Ph) and 58.11% (MG) unsaturated fatty acids, which corresponds to other published data (29). The yolk of an average-size quail egg (13.5-13.8 g) contains about 0.20-0.21 g PUFA which makes up 14.02-14.07% of total yolk lipids.

The healthy diet of contemporary men includes the weekly intake of 6 average-size (60-63 g) chicken eggs, which is equal to the consumption of 28 quail eggs. Taking into consideration of energy content of quail eggs cited by Bakalivanova (30), they provide 2,683 kJ energy in 49.5 g protein and 41.12 g fat. They also contain 25.07 g “ideal” protein (including 4.139 g lysine and 3.335 g methionine+cysteine) and 23.443 g unsaturated fatty acids, including 5.776 g essential PUFA (5.543 g Ώ6 and 0.233 g Ώ3).

According to recommendations of nutritionists about 6 chicken eggs per week provided by Bakalivanova (30) and their weight equivalent (28 quail eggs), we could recommend the daily intake of 4 average quail eggs (13.5-13.8 g). With them, one receives 3.44-3.72 g essential amino acids. This way, an 80-kg man with either intellectual activities or engaged in heavy physical labour could satisfy 34.4-37.2% and 13.2-14.4% of his daily needs, respectively. The daily consumption of 4 quail eggs provides 10.5% of needed lysine from the "ideal protein" and 14.1% of needs from methionine+cysteine. The obtained energy is 383.3 kJ, together with 3.360 g unsaturated fatty acids, including 0.790 g Ώ6 and 0.033 g Ώ3 fatty acids. With 4 quail eggs one receives 29.1 mg Ca, 89.5 mg P, 4.7 mg Mg, 0.76 mg Fe and 0.38 mg Zn.

CONCLUSION

The weight of Japanese quail eggs changed most consistently during the first 3 months of the production cycle ($P<0.001$). The average weight for the 7-month period was higher in Pharaoh quails (13.71±0.022) than in the MG breed (13.25±0.029; $P<0.001$). During the first 3 months, the shape of eggs became more elongated. The shape index of eggs from both breeds was similar – 77.36±0.084% (Ph) vs 77.14±0.088% (MG). The quality traits of egg albumen, yolk and eggshell were with highest values by the beginning of egg laying. Throughout the cycle, they gradually decreased and attained lowest values by the end of egg laying ($P<0.001$). The mean Haugh units and IQU values were respectively 89.04±0.131 and 56.08±0.291 (Ph); 88.99±0.142 and 56.26±0.314 (MG).

The yolk index varied between 0.234 and 0.577, with most stable status between production months 3 and 5. The mean yolk index values were 0.454±0.001 (Ph) and 0.447±0.001 (MG) ($P<0.001$). The eggshell thickness varied within 130-280 µm, with most consistent interbreed difference during the first two production months (7.7-7.3%; $P<0.001$). During the major part of the cycle, Ph quail eggs were with thicker eggshells – 213.77±0.527 µm vs 202.01±0.555 µm in MG ($P<0.001$). The relative share of albumen increased by 3.1% (Ph) – 3.8% (MG) over the production cycle, the share of yolk decreased by about 4 %, and that of eggshells – by 6.0 (Ph) to 8.6% (MG) ($P<0.001$).

The essential amino acid content of Japanese quail eggs comprised 50.36% of albumen protein and 48.65 % of yolk protein. The PUFA content in the phospholipid fraction of the yolk was almost 2.5 times higher than in the triglyceride fraction, whereas the

PUFA:SFA ratio was 0.52:1 vs 0.26:1-0.28:1 in the triglyceride fraction. Out of albumen mineral substances, the highest content was that of phosphorus, calcium and magnesium. The yolk was the richest in phosphorus and calcium, whereas the eggshell – in calcium.

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