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Determining the Most Effective Variables for Egg Quality Traits of Five Hen Genotypes

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ABSTRACT

This study was conducted to determine the availability of internal and external egg quality traits as selection criteria in White and Brown layers. For this reason, internal and external egg qualities have been determined in the sample eggs of two commercial and three native layer genotypes between 28 and 72 weeks of age. External quality traits such as; egg weight, shape index, breaking strength, shell thickness and egg specific gravity; and internal quality traits such as; albumen height, Haugh Unit, albumen index, yolk height, egg specific gravity and yolk color has been measured in 276 eggs of each genotype. Principal Component Analysis was applied to determine the most explanatory variables of total variance. Breaking strength and shell thickness of external egg quality traits and albumen height, albumen index and Haugh Unit of internal egg quality traits have been found in order to the most effective parameters in the genotypes. Shell thickness and breaking strength of external quality traits, and albumen height and albumen index were determined in an alternative approach, which grouped the genotypes according to live weights. External quality traits; breaking strength and shell thickness were effective in both medium heavy and light genotypes. But albumen height and albumen index in medium genotype, albumen height and Haugh Unit in light genotype were found effective according to internal quality traits. In conclusion, selection can be possible by determining some traits to improve the external and internal quality traits which include egg weight.

Key Words: Body weight; Egg quality; Layers; Principal component analyses; Selection traits

INTRODUCTİON

An increase of great production has been supplied in laying hens with the effects of genetic improvement, quality of feed and breeding techniques in the last five decades. In the future this increase will not be in the same level, but the studies about egg yolk, albumen and shell quality will continue to increase (Johnston & Gous, 2007). Particularly, most of the studies will be investigated to reduce the cholesterol level in the egg yolk (Harms & Hussein, 1993; Yannakopoulos *et al*., 1998) and to increase the yolk/albumen ratio in the egg (Harms & Hussein, 1993). Also, improving the shell quality will be another important subject to reduce the economic losses via cracks and the breakings of the egg (Hamilton *et al*., 1979; Tsang, 1992; Dunn *et al*., 2005). Although the albumen is a major indicator of internal egg quality; air cell size, albumen and yolk quality and the presence of blood or meat spots in the egg are the parameters, which determines the internal egg quality (De Ketelaere *et al*., 2004). The importance of the egg has increased since other industries, expect nutrition, started to use eggs. Egg yolk is still an important source for nutrients, and also used in non-food purposes like leather processing and a source of biologically active substances (Hartmann & Wilhelmson, 2001). Consequently, the studies about improving the quality and the quantity of egg components have been more important (Nys *et al*., 2008).

Egg quality is important for both layer and breeder flocks. Egg weight, yolk color and shell thickness are the most important quality traits of consumed egg (Stadelman, 1995). Shell thickness, breaking strength, specific gravity, albumen height, yolk height and some other quality traits are also important for hatching and consumed egg (Wolanski *et al*., 2007). Genotype, breeding systems, management, nutrition, age and changes in the weights of birds are the factors which affect the quality traits (Narushin & Romanov, 2002; Sarica *et al*., 2008, 2009). Previous studies showed the effects of different nutrients on egg quality (Hosseinzadeh *et al*., 2010); although determination of the some egg quality traits is pretty difficult, and it takes time to obtain some of these traits. Besides, an increase in the number of quality traits causes difficulties in the selection of parent stocks. Therefore, selecting the most determinative traits correlated with other traits facilitates in the selection of the breeds.

In this study we tried to execute the most determinative internal and external egg quality traits by using Principle Component Analysis (PCA).

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MATERIALS AND METHODS

The study was performed with three brown and two white layer genotypes. The brown genotypes were: ATAK, medium heavyweight local brown layer, ATAK-S, heavyweight local brown layer and SUPERBROWN, medium heavyweight imported brown layer. The white genotypes were: SUPERNICK, lightweight imported white layer and ATABEY, lightweight local white layer.

The experiment was conducted in a laying house containing conventional 3-tier cage blocks. Hens were randomly located to cages (3 hens per cage). In line with EU regulations requiring 550 cm^2 cage are per hen and 2 nipple drinkers per cage (Council Directive 1999/74/EC, 1999), the experiment was conducted with 705 cm^2 cage area per bird and a feeder length of 15.67 cm and 3 nipple drinkers per cage. Droppings were cleaned daily via a mechanical belt located under the cages. Light was applied for 15 h by energy-saving white fluorescent bulbs.

The eggs were collected daily from each cage between the ages of 28 and 72 weeks. Sample of eggs were kept in room temperature for 24 h and then analyzed. 1380 eggs (276 for each genotype) were completely analyzed. External egg quality parameters were egg weight, shape index, specific gravity, shell breaking strength and shell thickness while internal parameters were albumen height, albumen index, Haugh Unit score, yolk index, yolk height and yolk color. Yolk color was measured by roche color scale and specific gravity was determined by plunging eggs into salt solutions of different concentrations. The other quality traits were evaluated by methods described by Stadelman (1995) and Peebles and McDaniel (2004).

Data were classified according to genotypes, egg shell color and live weight groups. Principle Component Analysis (PCA Windows version of SPSS, release 12) was used to execute the most effectives of internal and external quality traits (Onder & Cebeci, 2009).

RESULTS

Mean values of external and internal quality traits of genotypes were given in Table I. Brown genotypes Superbrown and Atak-S had the heaviest eggs. Shell breaking strength data showed that imported genotypes' eggs were more resistant to breakings. Also, egg shell thicknesses of these genotypes were higher than local genotypes. White layers Supernick and Atabey had higher specific gravity, albumen height, albumen index and Haugh unit than brown genotypes, but brown layers had more yellow yolks. According to the result of Principle Component Analysis of these mean values, the shares of each trait in total variation were shown in Table II. Shell breaking strength was found the first determinative external quality trait of all genotypes. The second one was shell thickness for brown layers, and specific gravity for white layers. Albumen height was the most critical determinant of internal quality traits for SUPERBROWN, ATAK and ATABEY. The second marker was albumen index for SUPERBROWN and ATAK, Haugh unit was for ATABEY. For SUPERNICK and ATAK-S genotypes, the first determinant of internal quality traits was albumen index and the second albumen height. Nevertheless Haugh unit was equal determinant of the albumen height for ATAK-S genotype (Table II).

The data was also analyzed according to live weight groups. The mean values and the results were given in Table III. According to live weight groups, the first and the second determinative external quality traits was shell breaking strength and shell thickness. Albumen index was the important internal quality trait for light and heavy live weight groups, while albumen height was the second determinative trait. First trait was albumen height and the second one was albumen index for medium heavy weight group.

For light, medium heavy and heavy live weight groups of genotypes, 61.60, 60.63 and 53.62% of total variance explained on external quality traits and 81.42, 80.76% and 82.86% total variance explained on internal quality traits, respectively. Mean values (±SE) and the results of PCA of egg quality obtained by the classification according to color groups of genotypes were given in Table III.

In all egg shell color groups of genotypes, the first and the second determinant of external quality traits was shell breaking strength and shell thickness (Table IV). The first and second determinants of internal quality for white egg shell color group were albumen index and albumen height, respectively. The first determinant of internal quality traits for brown color groups was albumen height and the second albumen index. For white and brown egg shell color groups of genotypes, 61.60 and 57.50% of total variance explained on external; 81.42 and 81.32% of total variances explained on internal quality traits.

Coefficient of correlation, which were calculated for external and internal quality traits were given in Table V. The maximum correlation coefficient (0.979) was observed between albumen height and Haugh unit, the minimum correlation coefficient (0.009) was observed between shell thickness and albumen index. The maximum correlation (0.400) was observed between specific gravity and albumen index and the minimum correlation (-0.009) was observed between shell thickness and albumen index among external and internal quality traits. However, it was quite hard in practice to explain the relations between external and internal quality traits. Hence, canonical correlation coefficients were used to explain the relations between external and internal quality traits instead of Pearson correlation coefficients. Only one canonical correlation analysis was performed, because determinative external and quality traits nearly same among all genotypes.

Since the number of external quality traits was five and internal quality traits were six, 5 different canonical

Table I: Quality trait values of different layer genotypes

Quality Traits	Genotypes				
	ATABEY	SUPERNICK	ATAK	SUPERBROWN	ATAK-S
Egg Weight(g)	61.15±0.22d	64.98±0.27b	63.98±0.27c	67.60±0.29a	65.22±0.26b
Shape Index (%)	76.14±0.15b	75.02±0.16d	76.48±0.15b	78.08±0.17a	75.59±0.16c
Breaking Strength (kg/cm^2)	2.44±0.05d	3.42±0.06a	2.61±0.06c	3.16±0.07b	2.26±0.05e
Shell Thickness (mm)	0.38±0.002d	0.36±0.002b	0.346±0.002c	0.370±0.002a	0.333±0.002d
Specific Gravity(g/cm^3)	1.10±0.0004a	1.095±0.0004a	1.085±0.0003c	1.086±0.0003b	1.085±0.0003c
Albumen Height (mm)	7.68±0.08b	8.79±0.08a	7.09±0.08c	6.99±0.09c	7.58±0.09b
Albumen Index (%)	9.07±0.12b	10.63±0.12a	7.90±0.11d	7.61±0.12d	8.65±0.13c
Yolk Height (mm)	18.55±0.07b	18.77±0.07a	18.18±0.07a	18.56±0.07ab	18.76±0.08c
Yolk Index (%)	44.55±0.24b	44.74±0.22ab	43.76±0.23c	45.30±0.23a	45.15±0.23ab
Haugh Unit	86.58±0.49b	91.86±0.44a	82.14±0.52d	80.17±0.61e	84.69±0.55c
Yolk Color (Roche scale)	13.23±0.06c	13.05±0.06d	13.86±0.06a	13.58±0.06b	13.87±0.06a

a, b, c, d, e: Differences shown with letter are significant

Table II: Principal component analysis results of different layer genotypes (first component)

Traits	Genotypes				
	ATABEY	SUPERNICK	ATAK	SUPERBROWN	ATAK-S
External Quality Traits					
Breaking Strength (kg/cm^2)	0.796 (1)	0.811 (1)	0.861 (1)	0.814 (1)	0.813 (1)
Shell Thickness (mm)	0.566	0.662	0.795 (2)	0.770 (2)	0.673 (2)
Specific Gravity (g/cm^3)	0.667 (2)	0.694 (2)	0.611	0.733	0.523
Shape Index (%)	0.366	0.596	-0.150	0.012	0.378
Egg Weight (g)	-0.186	-0.309	0.152	0.110	-0.004
Internal Quality Traits					
Albumen Height (mm)	0.937 (1)	0.928 (2)	0.965 (1)	0.943 (1)	0.933 (2)
Albumen Index (%)	0.929	0.939 (1)	0.940 (2)	0.934 (2)	0.943 (1)
Haugh Unit	0.933 (2)	0.922	0.929	0.927	0.923 (2)
Yolk Index (%)	0.664	0.714	0.609	0.569	0.728
Yolk Height (mm)	0.715	0.697	0.626	0.611	0.728
Yolk Color (Roche Scale)	0.061	0.158	-0.069	0.142	-0.003

(1): First determinative factor of first component
(2): Second determinative factor of first component

Table III: Principal component analysis on egg quality traits and results (first component) of live weight groups of genotypes

Quality Traits	Light	PCA	Heavy Medium	PCA	Heavy	PCA
External Quality						
Egg Weight (g)	63.07±0.19b	0.142	65.77±0.21a	0.362	65.22±0.26a	-0.004
Shape Index (%)	75.58±0.11b	0.254	77.27±0.12a	0.196	75.59±0.16b	0.378
Breaking Strength (kg/cm^2)	2.94±0.05a	0.841 (1)	2.88±0.05a	0.816 (1)	2.26± 0.05b	0.813 (1)
Shell Thickness (mm)	0.36±0.001a	0.742 (2)	0.36±0.001a	0.795 (2)	0.333± 0.002b	0.673 (2)
Specific Gravity (g/cm^3)	1.10±0.0003a	0.619	1.09±0.0002b	0.675	1.085±0.0003b	0.523
Internal Quality						
Albumen Height (mm)	8.24±0.06a	0.933 (2)	7.05±0.06c	0.946 (1)	7.58±0.09b	0.933 (2)
Albumen Index (%)	9.85±0.09a	0.936 (1)	7.76±0.08c	0.936 (2)	8.65±0.13b	0.943 (1)
Yolk Height (mm)	18.66±0.05a	0.706	18.37±0.05b	0.606	18.76±0.08a	0.728
Yolk Index (%)	44.65±0.16	0.669	44.53±0.17	0.570	45.15±0.23	0.728
Haugh Unit	89.23±0.35a	0.931	81.17±0.39c	0.924	84.69±0.55b	0.933 (2)
Yolk Color (Roche scale)	13.14±0.04c	0.064	13.72±0.04b	0.037	13.87±0.06a	-0.003

a, b, c: Differences shown with letter are significant
(1): First determinative factor of first component
(2): Second determinative factor of first component

coefficients were calculated (Table VI) to introduce the relation between external and internal quality traits. The relation estimates between all the 5 canonical variable pairs were found statistically significant ($P<0.05$).

First estimated canonical correlation coefficient was 0.832. To show the structure of relation between external and internal quality traits, standardized canonical coefficients are given in Table VII and canonical weights in Table VIII.

Linear components, belongs to canonical variable pairs (U_1 & V_1) where the maximum relation was estimated, could be composed with use of canonical coefficients given in Table VI as:

$$U_1 = -4.713(AH) + 1.548(AI) + 3.438(HU) + 0.372(YI) - 0.551(YH) - 0.016(YC)$$

$$V_1 = 0.011(BR) + 0.025(ST) + 0.017(SG) + 0.049(SI) - 1.00(EW)$$

Table IV: Principal component analysis on egg quality traits and results (first component) of egg shell color groups of genotypes

Quality Traits	White	PCA	Brown	PCA
External Quality		%61.60		%57.50
Egg Weight (g)	63.07 ± 0.19b	0.142	65.59 ± 0.17a	0.310
Shape Index (%)	75.58 ± 0.11b	0.254	76.71 ± 0.09a	0.352
Breaking Strength (kg/cm^2)	2.94 ± 0.05b	0.841 (1)	2.67 ± 0.04a	0.822 (1)
Shell Thickness (mm)	0.355 ± 0.001a	0.742 (2)	0.349 ± 0.001b	0.777 (2)
Specific Gravity (g/cm^3)	1.095 ± 0.0003a	0.619	1.086 ± 0.0002b	0.593
Internal Quality		%81.42		%81.32
Albumen Height (mm)	8.24 ± 0.06a	0.933 (2)	7.22 ± 0.49b	0.938 (1)
Albumen Index (%)	9.95 ± 0.09a	0.936 (1)	8.08 ± 0.07b	0.936 (2)
Yolk Height (mm)	18.66 ± 0.05a	0.706	18.50 ± 0.04b	0.669
Yolk Index (%)	44.65 ± 0.16	0.669	44.74 ± 0.14	0.639
Haugh Unit	89.23 ±0.35a	0.931	82.34 ± 0.33b	0.920
Yolk Color (Roche scale)	13.14 ± 0.04b	0.064	13.77 ± 0.03a	0.045

a, b: Differences shown with letter are significant
(1): First determinative factor of first component
(2): Second determinative factor of first component

Table V: Pearson correlation coefficients between all quality traits

	Shell Thickness	Specific Gravity	Shape Index	Egg Weight	Albumen Height	Albumen Index	Haugh Unit	Yolk Index	Yolk Height	Yolk Color
Breaking Strength	0.528**	0.336**	0.062**	0.064**	0.138**	0.150**	0.118**	0.204**	0.166**	0.036
Shell Thickness		0.188**	0.072**	0.143**	-0.013	-0.009	-0.044	0.071**	0.043	0.016
Specific Gravity			0.012	-0.187**	0.358**	0.400**	0.368**	0.261**	0.244**	-0.143**
Shape Index				0.028	0.089**	0.087**	0.086**	0.243**	0.140**	0.028
Egg Weight					-0.031	-0.151**	-0.178**	0.032	0.249**	0.116**
Albumen Height						0.966**	0.979**	0.349**	0.428**	-0.109**
Albumen Index							0.958**	0.365**	0.424**	-0.131**
Haugh Unit								0.332**	0.381**	-0.119**
Yolk Index									0.821**	0.154**
Yolk Height										0.134**

**P<0.01

Table VI: Analysis results of canonical correlation coefficients

Canonical Variable Pairs	Canonical Correlation Coefficient	Canonical R^2 value	Eigen values	Degree of Freedom	Likelihood Ratio	P Value
U_1V_1	0.832	0.692	2.241	30	0.229	<0.0001
U_2V_2	0.445	0.198	0.247	20	0.745	<0.0001
U_3V_3	0.235	0.055	0.058	12	0.929	<0.0001
U_4V_4	0.108	0.012	0.012	6	0.983	0.001
U_5V_5	0.073	0.005	0.005	2	0.995	0.029

Table VII: Standardized canonical coefficients of canonical variable pairs

	External Quality Traits						Internal Quality Traits					
	Breaking Strength	Shell Thickness	Specific Gravity	Shape Index	Egg Weight		Albumen Height	Albumen Index	Haugh Unit	Yolk Index	Yolk Height	Yolk Color
V_1	0.011	0.025	0.017	0.049	-1.00	U_1	-4.713	1.548	3.438	0.372	-0.551	-0.016
V_2	0.298	-0.226	0.816	0.414	0.187	U_2	0.762	0.648	-0.857	0.642	-0.043	-0.184
V_3	0.332	0.273	-0.604	0.734	-0.144	U_3	1.095	-0.733	-0.798	1.502	-1.134	0.250
V_4	-0.114	0.990	0.111	-0.371	-0.087	U_4	0.167	3.224	-3.466	0.126	-0.427	-0.112
V_5	1.141	-0.556	-0.359	-0.395	-0.055	U_5	-0.981	1.371	-0.016	-0.478	0.291	0.981

When the coefficients of canonical variable pairs U_1 and V_1 examined regardless of signs (negative or positive), albumen height, albumen index and Haugh unit of internal quality traits, and egg weight of external quality traits was found more operative on the formation of canonical variables. It could be stated in other words that there was a strong relation between composed canonical variables and external, internal quality traits.

Canonical weights between external quality traits and internal quality traits were given in Table IX. There were high canonical cross loadings for albumen height, albumen index and Haugh unit with the canonical variable V_2. By squaring these figures (0.12, 0.13 & 0.11), it could be concluded that 12% of the variance in albumen height, 13% of the variance in albumen index and 11% of the variance in Haugh unit could be explained canonical variable V_2. Where

Table VIII: Canonical weights of canonical variable pairs

	External Quality Traits						Internal Quality Traits					
	Breaking Strength	Shell Thickness	Specific Gravity	Shape Index	Egg Weight		Albumen Height	Albumen Index	Haugh Unit	Yolk Index	Yolk Height	Yolk Color
V_1	-0.029	-0.105	0.199	0.021	-0.998	U_1	0.046	0.194	0.222	-0.014	-0.287	-0.143
V_2	0.456	0.129	0.850	0.441	0.045	U_2	0.778	0.808	0.733	0.798	0.733	-0.169
V_3	0.315	0.369	-0.407	0.756	0.043	U_3	-0.381	-0.406	-0.389	0.456	-0.019	0.408
V_4	0.417	0.913	0.256	-0.315	0.017	U_4	-0.338	-0.052	-0.321	-0.161	-0.223	-0.182
V_5	0.699	-0.049	-0.080	-0.367	-0.013	U_5	0.164	0.212	0.157	0.061	0.183	0.866

Table IX: Canonical weights between external quality traits and internal quality traits

	External Quality Traits						Internal Quality Traits					
	Breaking Strength	Shell Thickness	Specific Gravity	Shape Index	Egg Weight		Albumen Height	Albumen Index	Haugh Unit	Yolk Index	Yolk Height	Yolk Color
U_1	-0.025	-0.088	0.166	0.018	-0.830	V_1	0.038	0.161	0.184	-0.012	-0.239	-0.119
U_2	0.216	0.058	0.378	0.196	0.020	V_2	0.346	0.360	0.326	0.355	0.326	-0.075
U_3	0.074	0.087	-0.096	0.177	0.010	V_3	-0.089	-0.095	-0.091	0.107	-0.005	0.095
U_4	0.045	0.099	0.028	-0.034	0.002	V_4	-0.027	-0.006	-0.035	-0.017	-0.024	-0.019
U_5	0.051	-0.004	-0.006	-0.027	-0.001	V_5	0.012	0.016	0.011	0.005	0.013	0.063

Table X: Determined total variation on external and internal quality traits can be explained by canonical variables

	External quality traits				Internal quality traits		
	Variance extracted		Redundancy		Variance extracted		Redundancy
V_1	0.210	U_1	0.145	U_1	0.032	V_1	0.022
V_2	0.234	U_2	0.046	U_2	0.500	V_2	0.099
V_3	0.195	U_3	0.011	U_3	0.139	V_3	0.008
V_4	0.235	U_4	0.003	U_4	0.045	V_4	0.001
V_5	0.127	U_5	0.001	U_5	0.147	V_5	0.001

the canonical variable V_2 was;

$$V_2 = 0.298(BR) - 0.226(ST) + 0.816(SG) + 0.414(SI) + 0.187(EW)$$

Redundancy measures were calculated (Table X) to obtain information on how much of determined total variation on external and internal quality traits could be explained by canonical variables and how much of the variance in one set of variables was accounted for by the other set of the variables. According to the redundancy analysis results, 21% of total variation could be explained by canonical variable V_1 and 14.5% could be explained by canonical variable U_1 of external quality traits such as breaking strength, shell thickness, specific gravity, shape index, and egg weight. In spite of this, 3.2% of total variation could be explained by canonical variable U_1 and 2.2% could be explained by canonical variable V_1 of internal quality traits such as albumen height, albumen index, Haugh unit, yolk index, yolk height, and yolk color.

DISCUSSION

In the selection of external quality traits, using shell breaking strength and shell thickness as selection parameters may provide improvement. Also, albumen height may be used for the selection of internal quality traits. Haugh unit had reached acceptable levels as a result of studies previously done about selection on albumen height. This measure is incorporated into egg grading standards and accepted in markets. Improvement of shell strength is also continues. New studies should be made to reduce the number of broken and cracked eggs. As a result of these studies, the eggs will be kept for longer periods of time in the future (Arthur & Albers, 2003). When the egg is broken onto a flat surface, the height of the internal thick albumen has largely defined the quality of eggs for many years, because it is easily measured and relates well to the freshness of the egg (Silversides & Budgell, 2004). Also, shell strength (De Ketelaere *et al*., 2004) and albumen height (Wasburn, 1990) are heritable traits and are concern for commercial breeders. These data suggest that albumen height and shell strength have formed a part of the selection programs and used by the primary breeders (Silversides & Budgell, 2004; Zhang *et al*., 2005; Nys *et al*., 2008). On the other hand, it is possible to execute these traits which were used as selection criteria, with an easy calculating method of PCA, which is a toll that large number of independent variables can be systematically reduced to a smaller, conceptually more coherent set of variables. These "principal components" are a linear combination of the original variables (Dunteman, 1989). Lin *et al.* (2004) performed PCA to give an overview of the multidimensional data in egg weight, shell length and width. In that study they declared that first two components explained 80% of the total variation. Minvielle *et al.* (1999) utilized PCA to polymorphism data to reduce independent variables on first principal components. They declared that selected variables can be used as early selection criteria on Japanese quails. Combes *et al.* (2008) performed PCA on rabbit meat quality data to reduce dimension and after that used Canonical correlation analysis to highlight correlations between two groups of variables. Laçin *et al.* (2008) used CCA to determine the correlations between different body weights and egg quality parameters of Lohmann laying hens.

PCA applied to the obtained data to determine the most explanatory variables of total variance. Breaking strength and shell thickness of external egg quality traits and albumen height, albumen index and Haugh unit of internal egg quality traits have been found in order to the most effective parameters in the genotypes. Shell thickness and breaking strength of external quality traits, and albumen height and albumen index have been determinative in an alternative approach, which groups the genotypes according to live weights.

In conclusion, determination of the some egg quality traits is pretty difficult and it takes time to obtain some of these traits. By this way, selection can be possible by determining not all but some traits to improve the external and internal quality traits, which include egg weight.

REFERENCES

Arthur, J.A. and G.A.A. Albers, 2003. Industrial perspective on problems and ıssues associated with poultry breeding. *In:* Muir, W.M. and S.E. Aggrey (eds.), *Poultry Genetics, Breeding and Biotechnology*, pp: 1–12. Cabi Publishing, USA

Combes, S., I. Gonzalez, S. Dejean, A. Baccini, N. Jehl, H. Juin, L. Cauquil, B. Gabinaud, F. Lebas and C. Larzul, 2008. Relationships between sensory and physicochemical measurements in meat of rabbit from three different breeding systems using canonical correlation analysis. *Meat Sci.,* 80: 835–841

Council Directivd 1999/74/EC., 1999. Laying down minimum standards for the protection of laying hens. *Official J. European Communities*, No L 203: 0053–0057

De Ketelaere, B., F. Bamelis, B. Kemps, E. Decupeyre, J. De Baerdemaeker, 2004. Non-destructive measurements of the egg quality. *World's Poult. Sci. J*., 60: 289–302

Dunn, I.C., M. Bain, A. Edmond, P.W. Wilson, N. Joseph, S. Solomon, B. De Ketelaere, J. De Baerdemaeker, M. Scmutz, R. Preisinger and D. Waddington, 2005. Heritability and genetic correlation of measurements derived from acoustic resonance frequency analysis; a novel method of determining eggshell quality in domestic hens. *British Poult. Sci*., 46: 280–286

Dunteman, G.H., 1989. *Principal Component Analysis: Series: Quantitative Applications in the Social Sciences*. Sage Publications Inc, Newbury Park, CA, USA

Hamilton, R.M.G., K.G. Hollands, P.W. Voisey and A.A. Grunder, 1979. Relationship between eggshell quality and shell breakage and factors that affect shell breakage in the field-a review. *World's Poult. Sci. J*., 35: 177–190

Harms, R.H. and S.M. Hussein, 1993. Variations in yolk: albumen ratio in hen eggs from commercial flocks. *J. Appl. Poult. Res*., 2: 166–170

Hartmann, C. and M. Wilhelmson, 2001. The hen's egg yolk: a source of biologically active substances. *World's Poult. Sci. J*., 57: 13–28

Hosseinzadeh, M.H., Y. Ebrahimnezhad, H. Janmohammadi, A.R. Ahmadzadeh and M. Sarikhan, 2010. Poultry byproduct meal: Influenceon performance and egg quality traits of layers*. Int. J. Agric. Biol.,* 12: 547–550

Johnston, S.A. and R.M. Gous, 2007. Modelling the changes in the proportions of egg components during a laying cycle. *British Poult. Sci*., 48: 347–353

Laçin, E., A. Yıldız, N. Esenbuga and M. Macit, 2008. Effects of differences in the initial body weight of groups on laying performance and egg quality parameters of Lohmann laying hens. *Czech J. Anim. Sci*., 53: 466–471

Lin, H., K. Mertens, B. Kemps, T. Govaerts, B. De Ketelaere, J. De Baerdemaeker, E. Decuypere and J. Buyse, 2004. New approach of testing the effect of heat stress on eggshell quality: mechanical and material properties of eggshell and membrane. *British Poult. Sci.* 45: 476–482

Minvielle, F., J.L. Monvoisin, J. Costa, A. and Y. Maeda, 1999. Changes in heterosis under within-line selection or reciprocal recurrent selection: an experiment on early egg production in Japanese quail. *J. Anim. Breed. Genet*., 116: 363–377

Narushin, V.G. and M.N. Romanov, 2002. Egg physical characteristics and hatchability. *World's Poult. Sci. J*., 58: 297–303

Nys, Y., T. Burlot and I.C. Dunn, 2008. *Quality of Eggs: Better, any worse? International Egg Symposium*. The Return of the Good Eggs; November 26-28, Istanbul, WPSA Turkish Branch

Onder, H. and Z. Cebeci, 2009. Use and comparison of permutation tests in linear models. *Anadolu J. Agric. Sci*., 24: 93–97

Peebles, E.D. and C.D. McDaniel, 2004. *A Practical Manual for Understanding the Shell Structure of Broiler Hatching Eggs and Measurements of Their Quality*, p: 16. Miissippi Agriculture and Forestry Experiment Station, Bulletin, 1139

Sarica, M., S. Boga and U.S. Yamak, 2008. The effects of space allowance on egg yield, egg quality and plumage condition of laying hens in battery cages. *Czech J. Anim. Sci.,* 53: 346–353

Sarica, M., B. Yamak and U.S. Yamak, 2009. The effects of feed restriction in rearing period on growing and laying performances of white and brown layer hybrids in different adult body weights. *Asian J. Poult. Sci.,* 3: 30–41

Silversides, F.G. and K. Budgell, 2004. The relationships among measures of egg albumen height, pH and whipping volume. *Poult. Sci.,* 83: 1619–1623

Stadelman, W.J., 1995. Quality identification of shell eggs. *In*: Stadelman, W.J. and O.J. Cotterill (eds.), *Egg Science and Technology, Chapter* 3, pp: 39–66

Tsang, C.P.W., 1992. Calcitriol reduces egg breakage. *Poult. Sci.,* 71: 215–217

Yannakopoulos, A.L., A.S. Tserveni-Gousi and E. Christaki, 1998. Effect of natural zeolite on yolk:albumen ratio in hen eggs. *British Poult. Sci.,* 39: 506–510

Wasburn, K.E., 1990. Genetic variation in egg productiom. *In*: Crawford, R.D. (ed.), *Poultry Breeding and Genetics*, pp: 781–804. Elsevier, New York, USA

Wolanski, N.J., R.A. Renema, F.E. Robinson, V.L. Carney and B.I. Fanchert, 2007. Relationships among egg characteristics, chick measurements, and early growth traits in ten broiler breeder strains. *Poult. Sci.,* 86: 1784–1792

Zhang, L.C., Z.H. Ning, G.Y. Xu, Z.C. Hou and N. Yang, 2005. Heritabilities and genetic correlations of egg quality traits in Brown-egg dwarf layers. *Poult. Sci*., 84: 1209–1213

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