PHYSICAL CHARACTERISTICS AND MINERAL COMPOSITION OF POULTRY EGGS FROM LAYING HENS REARED AT DIFFERENT PRODUCTION SYSTEMS

Ali Karabayir[1], Mustafa Ogutcu[2], Nazan Arifoglu[3]

[1]Canakkale Onsekiz Mart University, Faculty of Agriculture,
Department of Animal Science, Terzioglu Campus, 17020 Canakkale, Turkey

[2]Canakkale Onsekiz Mart University, Faculty of Engineering,
Department of Food Engineering, Terzioglu Campus, 17020 Canakkale, Turkey

[3]Canakkale Onsekiz Mart University, Canakkale College of Applied Sciences,
Department of Food Technology, Terzioglu Campus, 17020 Canakkale, Turkey

Abstract

Different production systems such as intensive, extensive and organic production systems are known to greatly affect animal welfare and subsequently food products obtained from these systems. Though production quantity might decrease in extensive and organic production, quality products are expected to be obtained. In the present study, eggs from laying hens reared at three different production systems were investigated for their physical characteristics such as egg yolk and albumen colour, and also the mineral compositions of egg yolk and albumen were comparatively analysed.

Key words: *egg quality, physical characteristics, mineral composition*

1. INTRODUCTION

Eggs are regarded as an important part of human diet, since they are known to be rich sources of essential amino acids, fatty acids and micronutrients such as vitamins and minerals. With the increase in population and the rising consumer demand for quality food, the consumer consciousness of quality eggs is also a major concern of egg producers (Ledvinka, Zita & Klesalova 2012, Stadelman & Cotterill 1995).

For years, the main aim was to obtain the highest production rates from a unit production area, regardless of the animal welfare. But since 90's the rising consumer concern towards natural food products, has driven up the consciousness about environment and also animal welfare, thus leading to a new trend laying out the postulates of ecological farming. Thus, in 1999, the European Union adopted the minimum standards for the welfare protection of laying hens in cage, barn and free range production systems with EU Directive 1999/74/EC (Anonymous 1999a) and also laid down the rules for organic food production of animal origin under EC Regulation No 1804/1999 (Anonymous 1999b). Nowadays, there is a broad variety of egg products in the market, obtained from different production systems and of course with different prices. The demand for ecological food products, has led to the increase in producing more natural food products and nowadays, the consumers are opt to pay higher prices to products that are claimed to be from free-range or organic farms (Hidalgo et al. 2008, Kucukyilmaz et al. 2012, Minelli et al. 2007, Sekeroglu et al. 2007, Smiechowska & Dmowski 2005). Egg quality is stated to be greatly affected by the type of housing system, since it affects the welfare of the reared animals (Ledvinka, Zita & Klesalova 2012).

When organic production is considered, it is claimed that products from organic farms are more tasteful and also with better nutritional quality. The degree to which this claim is right was considered by a number of scientists and therefore, in literature, there is considerable research on comparison of the physical, chemical and microbiological characteristics of eggs obtained from different production systems. Nistor et al. (2015) evaluated the chemical and microbiological characteristics of eggs obtained from free range and conventional systems and found out that eggs from free-range system have slightly higher content of albumen protein and higher yolk lipid but much higher microbial load than the eggs from conventional system. In another study, the cholesterol and potassium content was higher in the organic eggs, while the conventional eggs had higher calcium content (Matt, Veromann

& Luik 2009). In accordance with these results, Minelli et al. (2007) found that organic eggs contained higher cholesterol and protein. On the other hand, Wang et al. (2009) reported that the egg yolks of blue-shelled layers raised in outdoor conditions contain lower cholesterol than those raised in indoor cages. On the contrary, Zemkova et al. (2007) evaluated the effect of different housing systems (conventional cages, enriched cages, litter system and outdoor system) on egg weight and cholesterol concentration and concluded that egg weight is not affected by the housing system, while the yolk cholesterol concentration was influenced by the housing system type, with cholesterol content being highest in the litter system and lowest in the eggs from enriched cages.

Eggs from different housing systems have been noticed to have different egg yolk colours, which greatly influenced consumer perceptions. Actually, the colour of egg yolks from conventional housing systems is mainly obtained as a result from the different synthetic pigments used in the feeds, while in organic poultry farming no synthetic colorants are allowed. Thus, organic egg yolks are somewhat paler in colour when compared with eggs from conventional farming (Hidalgo et al. 2008, Minelli et al. 2007).

Moreover, since there is a general consumer belief that organic eggs have better nutritional composition, the mineral composition of eggs was previously investigated by some researchers and rather controversial results have been reported. Sekeroglu et al. (2007) evaluated the effect of housing systems (deep litter, cage, farmyard and traditional village) on whole egg mineral contents. The researchers reported that egg Ca and Mg contents were not affected by the type of housing system, while K, Na, Zn, Cu, Fe and Mn contents exhibited variability with respect to production systems. Matt, Veromann and Luik (2009) detected that organic eggs contained lower Ca and P when compared with eggs from conventional farming. Kucukyilmaz et al. (2012) compared the mineral composition of of the edible portion of eggs and eggshells from organic and conventional systems and reported that P and Zn of the edible egg portion were lower in the organic eggs. On the other hand, there were no differences between the edible parts of organic and conventional eggs in terms of Ca, Mg, Fe and Cu concentrations. Giannenas et al. (2009) examined the trace minerals of yolk and albumen of eggs obtained from conventional, organic and courtyard production systems and concluded that trace element contents in yolks were higher than those found in albumens, while organic eggs were richest in Se. Furthermore, Mn yolk concentration was found lowest in courtyard eggs, while Cr was highest in courtyard eggs. Attia, Al-Harthi and Shiboob (2014) reported that mineral contents of edible parts of eggs from different sources varied, except for K.

In order to evaluate the quality of eggs from different production systems, in the present study the colour values and mineral composition of the egg yolks and albumens from courtyard, organic and conventional systems were examined and compared.

2. MATERIALS AND METHODS

2.1. Materials

In the present study, fresh eggs from conventional, organic and courtyard farms were collected and kept at +4^{o}C till analysis. All chemicals and reagents used during the analyses were of analytical grade and obtained from Merck (Darmstadt, Germany). Standard solutions of Ca, Mg, Na, K, Zn, Fe, Mn, Cr, Cu and Ni (Merck, Darmstadt, Germany) were used to obtain the calibration curves.

2.2. Physical characteristics

The physical characteristics of the sampled eggs were measure by weighing and with a caliper. The colour values of the egg albumens and yolks, in terms of L* (lightness), a* (redness/greenness) and b* (yellowness/blueness) values, were evaluated separately with a Minolta CR-400 colorimeter (Konica Minolta Sensing, Japan) which was calibrated with CIE lab standards prior to measurement.

2.3. Mineral analysis

First egg albumens and yolks were carefully separated from each other. The albumen and yolk samples were then digested with HNO_3 / HCl (2:1) (Aydin 2008). Afterwards, the mineral contents were measured using a Perkin Elmer (Optima 8000) inductively coupled plasma - optical emission spectrometer (ICP-OES). The operating parameters of the equipment were as in Table 1. All samples were measured in triplicate and the data were reported as mean ± standard deviation.

Table 1. Operating parameters for ICP-OES

Parameter	Description
Rf power	1400 watts
Plasma gas flow rate	10 L/min
Auxiliary gas flow rate	0.2 L/min
Nebulizer gas flow rate	0.80 L/min
Sample uptake rate	1.5 mL/min
Argon gas (high purity)	99.99%
Torch type High solids	Axial /Radial Optima 8X00 DV Quartz Torch
Nebulizer type	Concentric glass; cyclonic spray chamber
Nebulizer pressure	200 kPa
Pump rate	1.5 mL/min
Replicates	3
Sample uptake delay	30 s

2.4. Statistical analysis

The findings obtained in the present study were analyzed statistically by using Minitab 16.1.0 statistical software. The results are presented as mean ± standard deviation with three replicates. The differences among the egg yolk and albumen samples were estimated by applying the Tukey's test separately to the groups. The results were evaluated as significantly different at confidence level of $p<0.05$.

3. RESULTS AND DISCUSSION

Some of the physical characteristics measured within the present study are presented in Table 2. As can be seen from the results, the yolk diameter of the conventional eggs was smaller than that of the other samples, but this was mainly because of the fact that these eggs were lower in weight ($p<0.05$). The yolk height of the organic eggs was lower than that of the courtyard eggs, but was not significantly different from that of the conventional eggs. The physical traits of eggs have gained much interest, but in several studies, the physical quality was not found to be affected by the housing systems, but is mainly affected by the genotypes of the laying hens (Ledvinka, Zita & Klesalova 2012).

Table 2. Physical characteristics of the egg samples*

Samples	Egg Weight (g)	Albumen Diameter (mm)	Albumen Length (mm)	Yolk Diameter (mm)	Yolk Length (mm)
Courtyard	60.00±1.73a	88.92±7.63	6.21±0.27	38.10±0.98a	16.35±0.42a
Organic	60.00±6.12a	98.50±7.49	5.59±0.62	40.04±1.63a	14.51±1.40b
Conventional	47.80±4.02b	91.69±7.36	6.15±0.25	34.45±1.24b	15.71±0.79ab

*The different small letters in the same line show differences among the egg samples in each group.

The colour characteristics of any food product directly affect the consumers' attitude toward this food product. Especially, the colour of the egg yolks is an important factor influencing consumer preferences. Thus, a standard colour measurement system, CIE lab is used to evaluate the colour of food products. The colour values of the egg samples are given in Table 3. The colorimetric measurements have revealed that, there were no statistical differences among the L and a* values of the albumen of courtyard, organic and conventional eggs. On the other hand, the b* value of the courtyard egg albumen was significantly lower than that of the organic egg albumen ($p<0.05$), although there was no difference between the b* values of courtyard and conventional egg albumens. The L value of the organic egg yolk was significantly higher than that of the courtyard and conventional egg yolks, indicating that organic egg yolks are lighter in colour than the other egg yolk samples ($p<0.05$). But the a* value of the organic egg yolk was significantly lower than that of the other egg yolk samples ($p<0.05$). There were no significant differences among the egg samples in terms of the b* values of the yolks. Similarly to our results, Minelli et al. (2007) found out that the yolks of eggs from organic rearing system were paler in colour when compared with the egg yolks from cage type rearing system. A market survey on quality of eggs from different housing systems (cage, barn, free range and organic) revealed similar results: The Roche scale colour values of organic egg yolks were lower than the other samples (Hidalgo et al. 2008). Mugnai, Bosco and Castellini (2009), compared the egg yolk colours of the eggs of Ancona laying hens reared at conventional, organic and organic-plus (organic and pasture) rearing systems and concluded that, the darker egg yolk colour of the eggs of hens reared at organic-plus system was mainly due to the ingested grass under organic rearing system. The darker egg yolks from eggs obtained from conventional systems are mainly due to the fact that in conventional feeds synthetic colorants are used (Hidalgo et al. 2008, Minelli et al. 2007, Mugnai, Bosco & Castellini 2009).

Table 3. Colour parameters of the egg samples*

	Albumen			Yolk		
	Courtyard	**Organic**	**Conventional**	**Courtyard**	**Organic**	**Conventional**
L	74.82±10.05	73.01±7.70	77.86±9.61	50.48±0.53b	55.43±4.07a	51.06±1.52b
a*	-3.21±0.66	-3.86±0.57	-3.77±0.40	6.68±1.30a	3.17±3.30b	9.77±1.31a
b*	7.90±2.28b	11.67±2.90a	10.19±1.42ab	36.90±2.44	38.00±1.69	39.62±4.25

*The different small letters in the same line show differences among the egg samples in each group.

The mineral composition of a given food is a main concern with respect to human nutrition. Minerals are recognized as important micronutrients, since they have essential roles in human metabolism, bone and teeth health as well as the functioning of organs (Gropper, Smith & Groff 2005). In the present

study, the mineral composition of the egg albumen and yolk samples were determined and presented in Table 4.

Table 4. Mineral composition of the egg samples*

	Egg Albumen			Egg Yolk		
Minerals	**Courtyard**	**Organic**	**Conventional**	**Courtyard**	**Organic**	**Conventional**
Ca (mg/kg)	49.09±0.25c	79.50±1.09b	119.73±0.15a	639.8±2.36a	476.67±1.39b	233.50±2.60c
Mg (mg/kg)	60.07±0.40c	66.23±0.29b	87.00±0.72a	65.21±0.19b	66.86±0.86a	35.95±0.09c
Na (mg/kg)	1177±13.1a	1082.3±10.7b	1075.3±14.2b	338.27±6.48a	337.23±5.15a	264.23±9.72b
K (mg/kg)	855.37±8.85b	945.3±17.6a	735.10±13.77c	720.90±9.88b	807.07±2.08a	457.77±5.74c
Zn (mg/kg)	1.68±0.07b	4.71±0.03a	2.16±0.01c	26.74±0.19a	23.94±0.37b	9.51±0.12c
Fe (mg/kg)	2.43±0.03c	9.27±0.05a	7.43±0.01b	31.47±0.15a	21.62±2.31b	9.72±0.07c
Mn (µg/kg)	254.53±0.42c	518.83±2.06a	329.87±2.61b	1092.3±4.73a	724.57±1.90b	621.30±2.82c
Cr (µg/kg)	206.47±13.57c	627.23±2,64a	428.47±15.17b	303±3.75c	621.30±7.44a	462.13±11.97b
Cu (µg/kg)	1266.7±17b	1471±9.54a	1011.3±10c	1941.3±23.3a	1639±12.5b	1378±32.4c
Ni (µg/kg)	nd	1337.7±11.9b	3252±56.5a	nd	595.9±86.5	nd

*The different small letters in the same line show differences among the egg samples in each group.

The Ca content of organic egg albumen was lower than that of the conventional egg albumen, while this value showed opposite pattern when egg yolk was analyzed ($p<0.05$). Similar to our results Ca content of egg albumen, Matt, Veromann and Luik (2009) found that organic eggs in total had lower Ca content. The Mg contents of egg albumens and yolks were in the ranges of 60.07-87.00 and 35.95-66.86 mg/kg, respectively. While Matt, Veromann and Luik (2009) detected no differences between conventional and organic eggs in terms of Na and K contents, in our study, both egg albumens and yolks from different housing systems were different among each other when the Na and K concentrations are considered. The highest Zn content was found to be in courtyard egg yolks and the lowest Zn concentration was in conventional egg yolk ($p<0.05$). All types of egg yolks had much higher Zn contents than egg albumens. The Fe contents of egg albumens and yolks exhibited patterns similar to Zn contents (Table 4). The highest Mn, Cr and Cu contents were detected in organic egg albumens ($p<0.05$). On the other hand, when egg yolks are considered, the highest Mn and Cu concentrations were in courtyard samples, while organic egg yolk had the highest Cr content. Ni was detected only in organic egg albumen and yolk, as well as in conventional egg albumen. Similar to our results Sekeroglu et al. (2007) found out that different housing systems such as deep litter, cage, farmyard and village affect the Mn, Fe, Cu, Zn, Na and K contents of whole eggs. Contrary to our results, Kucukyilmaz et al. (2012) reported that Zn was lower in organic whole eggs when compared with conventional whole eggs. Giannenas et al. (2009) compared the trace mineral content of conventional, organic and courtyard egg yolks and albumens. Resembling to our results, courtyard egg yolks had the highest Zn contents, and Zn was found much higher in the yolk. Giannenas et al. (2009) detected the highest Cr in courtyard egg yolk and albumen, while our findings revealed that courtyard egg yolk and albumen were poorest sources of Cr (Table 4).

4. CONCLUSION

In the present study, some of the colour parameters as well as the mineral composition of egg yolks and albumens of eggs obtained from different husbandry systems such as courtyard, organic and conventional were evaluated. As it was expected, the yolk colour of organic eggs was paler than the other yolks, most probably due to the fact that in organic egg production, no synthetic pigments are permitted for use in feeds. On the other hand, different production systems were found to affect the mineral composition of egg yolks and albumens.

REFERENCES

Anonymous 1999a, *Council Directive 1999/74/EC*, 19 July 1999, European Union Council, *Official Journal of the European Communities*, L203, pp. 53-57.

Anonymous 1999b, *Council Regulation (EC) No 1804/1999*, 19 July 1999, European Union Council, *Official Journal of the European Communities*, L222, pp. 1-33.

Attia, YA, Al-Harthi, MA & Shiboob, MM 2014, 'Evaluation of quality and nutrient contents of table eggs from different sources in the retail market', *Italian Journal of Animal Science*, vol. *13*, *no.* 2, pp. 369-376.

Aydin, I 2008, 'Comparison of dry, wet and microwave digestion procedures for the determination of chemical elements in wool samples in Turkey using ICP-OES technique', *Microchemical Journal*, vol. 90, no. 1, pp. 82–87.

Giannenas, I, Nisianakis, P, Gavriil, A, Kontopidis, G & Kyriazakis, I 2009, 'Trace mineral content of conventional, organic and courtyard eggs analysed by inductively coupled plasma mass spectrometry (ICP-MS)', *Food Chemistry*, vol. 114, no. 2, pp. 706-711.

Gropper, SS, Smith, JL & Groff, JL 2005, 'Macrominerals, microminerals, ultratrace elements', in *Advanced nutrition and human metabolism*, 4th edn, Thomson Wadsworf, Belmont, USA, pp. 378-500.

Hidalgo, A, Rossi, M, Clerici, F & Ratti, S 2008, 'A market study on the quality characteristics of eggs from different housing systems', *Food Chemistry*, vol. 106, no. 3, pp. 1031-1038.

Kucukyilmaz, K, Bozkurt, M, Yamaner, C, Cinar, M, Catlı, AU & Konak, R 2012, 'Effect of an organic and conventional rearing system on the mineral content of hen eggs', *Food Chemistry*, vol. 132, no. 2, pp. 989-992.

Ledvinka, Z, Zita, L & Klesalová, L 2012, 'Egg quality and some factors influencing it: a review', *Scientia Agriculturae Bohemica*, vol. 43, no. 1, pp. 46-52.

Matt, D, Veromann, E & Luik, A 2009, 'Effect of housing systems on biochemical composition of chicken eggs', *Agronomy Research*, vol. 7, no. 2, pp. 662-667.

Minelli, G, Sirri, F, Folegatti, E, Meluzzi, A & Franchini, A 2007, 'Egg quality traits of laying hens reared in organic and conventional systems', *Italian Journal of Animal Science*, vol. 6, Supp. 1, pp. 728-730.

Mugnai, C, Dal Bosco, A & Castellini, C 2009, 'Effect of rearing system and season on the performance and egg characteristics of Ancona laying hens', *Italian Journal of Animal Science*, vol. 8, no. 2, pp. 175-188.

Nistor, LI, Albu, A, Nistor, AC & Usturoi, MG 2015, 'Aspects of eggs quality provided from free range and conventional systems', *The Journal of Microbiology, Biotechnology and Food Sciences*, vol. 5, *no.* 2, pp. 186-189.

Sekeroglu, A, Sari, H, Mendil, D & Sarica, M 2007, 'Effects of housing systems on some mineral contents of hen's eggs', *Asian Journal of Chemistry*, vol. 19, no. 4, pp. 2939-2944.

Smiechowska, M & Dmowski, P 2005, 'Influence of raising method on the quality of hen eggs', *Polish Journal of. Food and Nutrition Sciences,* vol. *14*, no. 55, Suppl. 1, pp. 117-120. 55.

Stadelman, WJ & Cotterill OJ 1995, *Egg science and technology*, 4th edn, Haworth Food & Agricultural Products Press, New York.

Wang, XL, Zheng, JX, Ning, ZH, Qu, LJ, Xu, GY, & Yang, N 2009, 'Laying performance and egg quality of blue-shelled layers as affected by different housing systems', *Poultry Science,* vol. 88, no. 7, pp. 1485-1492.

Zemková, Ľ, Simeonovová, J, Lichovníková, M, & Somerlíková, K 2007, 'The effects of housing systems and age of hens on the weight and cholesterol concentration of the egg', *Czech Journal of Animal Science,* vol. 52, no. 4, pp. 110-115.