potravinárstvo®

Slovak Journal of Food Sciences

Potravinarstvo Slovak Journal of Food Sciences
vol. 13, 2019, no. 1, p. 402-407
https://doi.org/10.5219/1060
Received: 10 February 2019. Accepted: 13 March 2019.
Available online: 28 June 2019 at www.potravinarstvo.com

ISSN 1337-0960 (online)

COMPARISON OF CHEMICAL COMPOSITION OF EGGS FROM LAYING HENS HOUSED IN DIFFERENT PRODUCTION FACILITIES: A MARKET STUDY

Jaromír Pořízka, Adam Michalec, Pavel Diviš

ABSTRACT

Eggs as a part of human diet dates to the prehistoric period. After the domestication of *Gallus* species, *Gallus gallus domesticus* and their eggs spread across the globe. Eggs proved to be one of the best and affordable sources of nutritionally important components in human diet, such as proteins, vitamins, lipids and some dietary significant elements. Progress in egg production methods, in European union, is recently mostly focused on the improvements in the field of welfare of laying hens, which is part of the plan set by European union council directive 1999/74/EC. Nowadays there are 4 main egg production systems divided by the way of keeping laying hens – Enriched cage, Free range, Barn and Organic. The aim of this study was to evaluate the impact of different hens housing systems on elemental (Ca, K, Mg, Na, P, Ca, K, Zn), total protein and lipid composition of whole eggs, yolk and albumen. Elemental analysis was performed by ICP-OES, total lipid content by Kjehldahl method and total lipids by Soxhlet extraction. Differences in whole egg were found in 8 from 9 tested parameters – K, Mg, Ba, Fe, P, Zn, total lipids and proteins. Assessment of the differences were done by ANOVA and Tukey`s test. Production systems were also successfully differentiated by principal component analysis. It was found that eggs from alternative production systems did not exhibit higher nutritional value than eggs from conventional cage facilities. In the case of total protein, conventional eggs contained highest average amount. It was also evident, that impact on chemical composition is difficult to assign to production system in general, which was confirmed by alternative studies from this field, which in many cases considerably differs.

Keywords: eggs; laying hens; housing; elemental analysis; proteins

INTRODUCTION

Eggs as a part of human diet dates to the prehistoric period. After the domestication of *Gallus* species, *Gallus gallus domesticus* and their eggs spread across the globe. Eggs proved to be one of the best and affordable sources of nutritionally important components in human diet, such as proteins, vitamins (A, B_5, B_7, B_9, B_{12}, K, D, E), lipids and some dietary significant elements (P, Na, K, Ca, Mg, Fe). It is also having relatively high average energy value of 547 kJ.100g^{-1} of whole raw egg **(Belitz et al., 2009; Finglas et al., 2015; Bulková, 1999)**. World egg production rises by 18 percent from 2006 to 2016 to almost 74 million metric tons, as demand for eggs is growing due to rising population, incomes and dietary acceptance. Production in the European union is projected to be quite steady with rising in next decade from 7.7 in 2016 to 8.2 million metric tons in 2026 **(WATT, 2018)**. Progress in egg production methods, in European union, is recently mostly focused on the improvements in the field of welfare of laying hens, which is part of the plan set by European union **council directive 1999/74/EC**. This regulation banned barren battery cages which were replaced by enriched cages with more space, height and nesting area. Conventional enriched cages system covered 53.2% of EU egg production in 2017 and nowadays there are 4 main egg production systems divided by the way of keeping laying hens – Enriched cage, Free range, Barn and Organic. Special group of eggs are those produces in home breeding conditions. Information about the production system must be shown as a part of code on the egg shell.

There are various motivations of modern consumers to select alternatively produced eggs - especially from organic production. This motivation is mainly driven by demand for healthy, nutritionally balanced food products and also by increased perception of the area of environmental friendliness and animal welfare. **(Kralik et al., 2008; Filipiak-Florkiewicz et al., 2017; Shafie and Rennie, 2012; Schleenbecker and Hamm, 2013)**. A growing interest of consumers for non-conventional foods prompted the research activity to assess the real impact of different egg production systems on overall quality of product. **Filipiak-Florkiewicz et al. (2017)** conducted comparison of organic, nutraceutical and conventional eggs with focus on fatty acid profile, elemental analysis and some physical parameters like colour and rheological properties of mayonnaise made from studied eggs. Results of this study revealed significant differences ($p \leq 0.05$) in the chemical composition. Organic and nutraceutical eggs were characterized to be nutritionally more beneficial in comparison with conventional production. Similar study was proceeded by **Anderson (2011)**, focused on comparison of fatty acid, cholesterol and vitamin A and E composition of eggs from cage and rage production facilities. Significant differences ($p \leq 0.05$) were found in total fat content, which was higher in eggs from range housing. It is also worth mention a market study carried out by **Hidalgo et al. (2008)**. This paper deals with comparison of Italian eggs from barn, cage, free range and organic housing in terms of 41 physical and chemical parameters. Differences were found in whipping capacity, foam consistency, albumen quality and shell resistance to breaking. Multivariate statistical analysis differentiated cage eggs from alternative (organic, barn and free range). It was also concluded, that apart of psychological and ethical motivations, differences in quality of eggs did not justify the higher prices for alternatively produced eggs.

The aim of this study is to evaluate the impact of different hens housing systems on elemental (Ca, K, Mg, Na, P, Ca, K, Zn), total protein and lipid composition of yolk and albumen.

Scientific hypothesis

This study is based on hypothesis whether different approaches of laying hens housing can be significantly reflected in basic chemical composition of eggs. Testing of this hypothesis is an extension of previously published studies, enriching the field by actual data from Czech Republic egg market and by analysis of domestically (home) produces eggs and eggs from improved cage lined by litter material.

MATERIAL AND METHODOLOGY

Samples and sample preparation

Total of 20 batches of eggs from 5 different laying hens housing systems were obtained - Enriched cage, Enriched cage with litter bedding, Free range, Home and Organic. Every batch contained 6 eggs of M size (53 – 63 g) with similar laying period of first week in February 2018. All the batches were from different producers from Czech Republic and were acquired in standard commercial retail network. Eggs produces by home breeding and laying were obtained directly from small village farmers in Brno countryside region (Czech Republic).

Sample preparation

Every batch of 6 eggs was divided into 2 parallel parts of 3 eggs. Albumen and yolk were mechanically separated and was dried on petri dishes at 70 °C for 8 hours. Dried samples were homogenized. Total of 40 sub-samples from 5 different systems were prepared. Microwave digestion system was used for the preparation of samples for elemental analysis on ICP-OES. Amount of 200 mg of albumen and yolk samples were transferred into the teflon cartridges with 5 mL of 65% HNO_3 and 2 mL of concentrated H_2O_2 (Analytika Praha, Czech Republic). Digestion itself was performed by microwave digestion system Milestone 1200 (Milestone, USA). After the decomposition, samples were transferred into 25 mL volumetric flasks, diluted with deionized water (Elga purelab Classic, Veolia water systems, UK) and filtrated through 0.45 µm nylon syringe filters.

Determination of total proteins

Total proteins in samples of albumen and yolk were determined by standard Kjelhdahl method. Mineralization was done by mineralization unit KT-8s (C. Gerhardt & Co, Germany). Digestion of 1 g sample was proceeded at 420 °C for 90 min. Distillation of ammonia was performed by Vapodest steam distillation instrument (C. Gerhardt & Co, Germany) and collected into titration flask with 0.05 M H_2SO_4. Excess of sulfuric acid was titrated with 0.1 M NaOH. Conversion factor from nitrogen to protein content was 6.25, which is standard for eggs.

Determination of total lipids

Determination of total lipids was realized only in samples of yolk due to trace concentration level in albumen **(Finglas et al., 2015)**. Soxhlet method was selected for the extraction of lipids. Lipids from 4 g of yolk sample were extracted into 150 mL of petroleum ether by automatic extraction Soxhlet instrument Soxtherm (C. Gerhardt & Co, Germany). Extraction proceeded for 2 hours at 150 °C. Petroleum ether was distilled away from extraction flask and fats content was determined gravimetrically.

Determination of elemental composition

Elemental analysis of yolk and albumen was performed by ICP-OES Horiba Jobin Yvonne Ultima 2 (Horiba Scientific, France) with measurement conditions of 15 rpm of peristaltic pump; RF power 1300 W, argon plasma gas flow 14 $L.min^{-1}$, auxiliary gas flow 0.15 $L.min^{-1}$, sheath gas
0.7 $L.min^{-1}$ (K, Na, Mg, Ca) and 0.2 $L.min^{-1}$ (P, Zn, Fe, Mn). Instrument was calibrated by standards made from individual 1 $g.L^{-1}$ stock solutions (Analytika Praha, Czech Republic). Calibration was prepared by the standard addition method into the blank solutions used for sample digestion.

Statistical analysis

Data analysis and statistical evaluation were performed in Microsoft Excel (Microsoft, USA) and XL-stat (Addinsoft, France). Results were processed by various statistical approaches. Before the main data analysis, results were tested for outliners and data distribution. The Grubbs test for outliners did not revealed any outlined values between the 5 tested groups of eggs and data showed a normal Gaussian distribution.

Analysis of variance (ANOVA) was used to evaluate chemical parameters which exhibited statistically significant differences between the groups of eggs from different production systems. *p*-values as a result of this analysis is provided. Tukey pair test was used for evaluation of inter-group comparison.

Principal component analysis (PCA) based on Pearson correlation was used for multivariate characterization of samples and to find specific links between observations (egg samples) and original variables (chemical composition). The main goal of this analysis was to find similarities and dissimilarities between different groups of eggs to obtain a potential sample grouping according to a corresponding egg production system. Results of PCA were visualized by the projecting the observations onto biplot of principal components and original variables.

RESULTS AND DISCUSSION

Total proteins and lipid content, combined with elemental composition, are important factors indicating the basic nutritional values of the eggs. All these chemical components are distributed differently in yolk and albumen. Summary of the analysis of eggs, produced by different production facilities are presented in Table 1. Results are divided into three parts for whole egg samples and for dried yolk and albumen.

Proteins are probably most important dietary element of eggs and has a high level of digestibility in human organism **(Geissler and Powers, 2010)**. Differences in protein content (connected to housing systems) were found to be statistically significant (p = 0.007). Deeper analysis confirmed these differences only in albumen part of tested eggs. Highest average protein content was found in eggs from free range breeding (42.6 ±8.2 g.100g^{-1}). Almost similar results were observed in eggs from conventional cage facilities (42.5 ±2.9 g.100g^{-1}). Lowest concentration of total proteins was determined in eggs from home and organic systems (31.1 ±7.1; 31.1 ±7.1 g.100g^{-1}). Comparison of these results with other studies showed inconsistency in assessment of egg production systems influence on protein composition of eggs. **Filipiak-Florkiewicz et al. (2017)** and **Minelli et al. (2016)** reported that organic eggs contained more proteins that the eggs from conventional production. On the contrary, **Matt et al. (2009)** proved that conventional eggs contained higher amounts of proteins than organic. They tested eggs

Table 1 Mean values ±SD of chemical components of yolk and albumen. ANOVA *p*-value significance testing and Tukey`s test.

Variable	Housing system					
	Cage (n = 4)	**Litter (n = 4)**	**Home (n = 4)**	**Organic (n = 4)**	**Range (n = 4)**	***p***
			Yolk (dry)			
Ca (mg.g^{-1})	2.55 ±0.22	2.41 ±0.23	2.45 ±0.31	2.62 ±0.37	2.41 ±0.07	n.s.
K (mg.g^{-1})	1.63**b** ±0.1	1.8**b** ±0.12	2.13**a** ±0.09	1.68**b** ±0.1	1.40**c** ±0.02	***
Mg (mg.g^{-1})	0.16 ±0.03	0.14 ±0.007	0.15 ±0.006	0.13 ±0.02	0.12 ±0.01	n.s.
Na (mg.g^{-1})	1.09**a** ±0.18	0.90**ab** ±0.01	0.82**bc** ±0.03	0.76**bc** ±0.06	0.66**c** ±0.06	**
Fe (mg.g^{-1})	0.01**ab** ±0.001	0.01**ab** ±0.003	0.02**a** ±0.003	0.01**b** ±0.001	0.01**ab** ±0.004	*
P (mg.g^{-1})	2.45**ab** ±0.05	2.80**ab** ±0.15	2.78**ab** ±0.24	2.35**b** ±0.17	3.24**a** ±0.56	*
Zn (mg.g^{-1})	0.05**ab** ±0.002	0.04**ab** ±0.001	0.06**a** ±0.02	0.04**ab** ±0.001	0.03**b** ±0.003	*
Lipids (%)	52.5**ab** ±1.23	51.8**ab** ±1.41	55.2**ab** ±0.33	43.3**b** ±3.88	50.2**a** ±0.49	***
Proteins (%)	20.9 ±1.4	18.2 ±1.2	16.4 ±2.8	18.6 ±0.3	21.2 ±4.8	n.s.
			Albumen (dry)			
Ca (mg.g^{-1})	0.436 ±0.1	0.719 ±0.001	0.456 ±0.07	0.615 ±0.11	0.50 ±0.22	n.s.
K (mg.g^{-1})	2.14 ±0.2	2.40 ±0.36	2.05 ±0.02	2.33 ±0.18	2.02 ±0.1	n.s.
Mg (mg.g^{-1})	0.177**ab** ±0.03	0.142**a** ±0.02	0.203**bc** ±0.002	0.156**bc** ±0.01	0.132c ±0.01	**
Na (mg.g^{-1})	2.79 ±0.37	2.73 ±0.19	2.35 ±0.05	2.68 ±0.05	2.48 ±0.06	n.s.
P (mg.g^{-1})	0.066**b** ±0.01	0.043**b** ±0.01	0.056**b** ±0.01	0.134**a** ±0.05	0.056**b** ±0.01	**
Proteins (%)	22**a** ±1.5	17.8**ab** ±0.9	14.6**ab** ±4.3	13.6**b** ±3.4	21.1**a** ±3.4	**
			Whole (dry)			
Ca (mg.g^{-1})	2.99 ±0.32	3.13 ±0.234	2.91 ±0.382	3.23 ±0.481	2.91 ±0.292	n.s.
K (mg.g^{-1})	3.77**ab** ±0.297	4.2**b** ±0.477	4.18**b** ±0.021	4**ab** ±0.283	3.42**a** ±0.121	**
Mg (mg.g^{-1})	0.341**bc** ±0.059	0.28**ab** ±0.017	0.355**c** ±0.005	0.291**abc** ±0.029	0.252**a** ±0.015	**
Na (mg.g^{-1})	3.88**b** ±0.552	3.63**ab** ±0.2	3.17**a** ±0.085	3.44**ab** ±0.105	3.14**a** ±0.117	*
Fe (mg.g^{-1})	0.013**ab** ±0.004	0.012**ab** ±0.0001	0.015**b** ±0.002	0.008**a** ±0.0001	0.012**ab** ±0.002	*
P (mg.g^{-1})	2.51**a** ±0.052	2.85**ab** ±0.161	2.83**ab** ±0.247	2.48**a** ±0.221	3.3**b** ±0.571	*
Zn (mg.g^{-1})	0.047**ab** ±0.005	0.039**ab** ±0.003	0.058**b** ±0.017	0.039**ab** ±0.004	0.032**a** ±0.0001	*
Lipids (%)	52.5**bc** ±1.2	51.8**bc** ±1.41	55.2**c** ±0.331	43.3**a** ±3.9	50.2**b** ±0.491	***
Proteins (%)	39.4**c** ±2.9	33**a** ±2.1	28.5**abc** ±7.1	29.6**ab** ±3.7	39.12**bc** ±8.2	**

Note: ANOVA * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$; n.s.: non significant. Letters **a.b.c.d** are groups obtained by Tukey pari test. Provided when ANOVA $p \leq 0.05$.

laid in winter season (January), which is similar to our study.

It could be assumed, that conventional cage system is providing stable condition during the year, but it is not supported by the results from another cage system – with litter bed. Eggs from this system contained approximately 10% less proteins than from standard cages. It is also necessary to mention the variability of production. Highest variability of results was observed in group of eggs produces in home breeding conditions and in free range facilities. It was highly expected for eggs produces in domestic conditions due to the high variability in feed and breeding conditions. Eggs from both cage systems on the other hand showed lowest standard deviation within the observations. Overall, the correlation between the housing systems and the protein composition of eggs is not easily feasible, unless the analysis is expanded by more detailed information about feed, age, breed, climatic and other conditions. As **Lordelo et al. (2016)** concluded, those parameters are difficult to control in systems based on free movement of hens (including organic). Most problematic is observation of amount of time the hen spends in exterior where they can feed on wild plants and insects.

Another statistically significant influence (p <0.0001) of production systems was found in total lipid content in egg yolk. Highest average amount of fat was found in yolk of home produces eggs (55.2 ±0.33%). On the basis of consultation with small farmers was found, that hens are mostly fed by corn, beet, boiled potatoes, sunflower, maize and fatty pastries. It is not an exception that chicken diet is supported by rest of the meat and the offal. All these feeds are rich in lipids, which was reflected in high amount in yolk. Beside the non-standard domestic production, the lipids were most abundant in eggs from both cage systems (52.5 ±1.23 and 51.8 ±1.41%). It is probably caused by minimal possibility of animal free movement and by specific and unified diet. Fodder mixtures in cage systems are based on corn and soybean enhanced by feed fat with minimal contribution of vegetables. As in the case of proteins, eggs from organic production contained significantly lower content of fat than other tested samples (43.3 ±3.9%). The fact, that eggs from free range system contained the second least fat content (50.2 ±0.49%) offers explanation in free movement of hens. Articles published in this field again showed various results in assessment of impact of egg production systems on total lipid content. Similar results, like in presented article, was found in research of **Lordelo et al. (2016)** with lowest amount of total fatty acid in eggs labeled as organic. **Matt et al. (2009)** also proved, that conventional eggs are better source of lipids. In opposite, there is a study from **Filipiak-Florkiewicz et al. (2017**), with the finding, that organically produced eggs contained 9.2% more fat than conventional. **Anderson (2011)** found higher fat content in the eggs from the range production environment than from the cage facilities. It was explained by the contribution of wild seeds and insects on feed composition of hens. This effect will be probably weaker in winter time of year which was the case of our study. **Samman et al. (2009)** discovered only little difference between the fatty acid composition of eggs and no differences in total lipid content of conventional and organic eggs. This result is supported by the study of **Hidalgo et al. (2008)** with non-significant differences between the eggs from cage, free range, barn and organic facilities.

Among mineral compounds, statistically significant differences (p <0.05) were found within all tested elements except for calcium which exhibit stable level among all the tested samples.

The most abundant element in whole eggs was potassium. Average concentration ranges from average 3.42 to 4.2 mg.g^{-1}. Highest average concentration of K was observed in eggs from domestic farms and in eggs from cage system supported with litter bed (4.18 ±0.021 and 4.2 ±0.477 mg.g^{-1}). Laying hens can feed on straw bed in cage, which is mostly from wheat. This kind of straw contains more than 10 g.kg^{-1} of potassium **(Plazonić et al. 2016)**. Lowest average concentration was determined in eggs from free range production (3.42 ±0.12 mg.g^{-1}). In comparison with alternative studies, **Filipiak-Florkiewicz et al. (2017)** and **Matt et al. (2009)** discovered relatively higher concentration of K in organic eggs compared to conventional.

Another significant difference (p = 0.015) in microelement group was found in average concentration of sodium. Differences were found, similarly to potassium, only in yolk part of eggs. Highest amount of Na was observed in eggs from both cage systems (3.88 ±0.552 and 3.88 ±0.552 mg.g^{-1}). According to Tukey`s test, organic eggs were also involved in this group. The group with low concentration of potassium included eggs from home and free-range systems (3.17 ±0.085 and 3.14 ±0.117 mg.g^{-1}). It is obvious, that eggs from hens with natural free movement contains lower amount of Na, which is probably utilized in larger quantities as an electrolyte in animal organism **(Lehninger et al., 2013)**.

Content of magnesium was also significantly affected by the egg production systems. Magnesium is mostly presented in egg shell, but it can be also found in edible part of egg. If we neglect non-standard domestic production, highest average concentration of Mg was determined in eggs from conventional cage production (0.341 ±0.059 mg.g^{-1}), but according to Tukey`s test, this set of eggs belong to same group with litter and organic samples (p = 0.05). It only differs from free range production with lowest average concentration (3.14 ±0.117 mg.g^{-1}). These results can be compared with work of **Filipiak-Florkiewicz et al. (2017)**. It was confirmed that yolk of conventionally produces eggs contained higher amount of magnesium. It is likely to be caused by the stable addition of mineral additives into the feed of hens housed in cages. However, **Küçükyılmaz et al. (2012)** did not found significant differences (p >0.05) between magnesium content in edible part of conventional and organic eggs. In terms of phosphorus content, it was most abundant in eggs from free range production, but with relatively high standard deviation (3.3 ±0.571 mg.g^{-1}). Lowest average of phosphorus concentration was determined in eggs from organic and conventional cage system (2.48 ±0.221 and 2.51 ±0.052 mg.g^{-1}).

Microelements are also dietary important components of eggs, especially Fe and Zn. These elements play a role in many metabolite pathways, redox reactions and are often part of metalloproteins and its bioavailability from eggs is similar like from meat and cereals **(Geissler and Powers, 2010)** According to analysis of variance, statistically

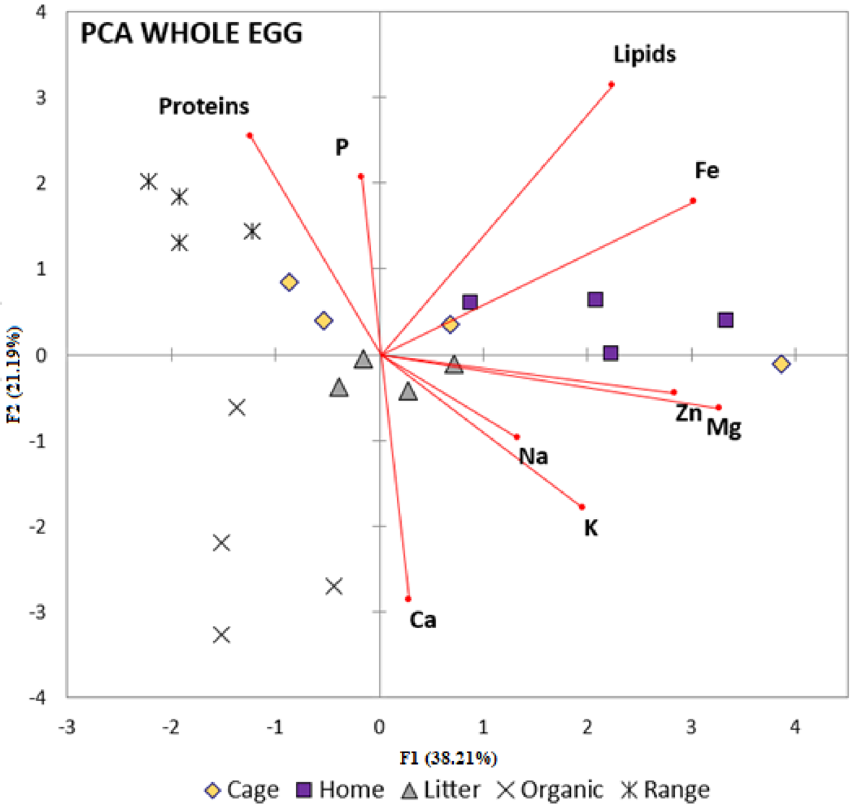

Figure 1 PCA biplot of whole egg observations with original variables projected into a 2-D factor plane of principal components F1 and F2.

significant differences were found (p = 0.019 for Fe and p = 0.014 for Zn).

Highest average concentration of iron and zinc, which are mostly presented in yolk of eggs, was found in eggs from home production (0.015 ±0.002 $mg.g^{-1}$ Fe and 0.058 ±0.017 $mg.g^{-1}$ Zn). This is probably caused by the fact, that domestically housed hens are often fed by animal diet based on meat and offal, which is rich source of iron and zinc. Differences between other 4 standard production systems did not exhibit significant differences (p >0.05). **Küçükyılmaz et al. (2012)** and **Filipiak-Florkiewicz et al. (2017)** determined higher content of iron in conventionally produced eggs compared to organic. Cages and its corrosion can be source of iron and zinc, which is one of probable causes of this phenomenon.

As an addition to univariate data analysis by ANOVA and Tukey`s test, multivariate classification of samples was evaluated by Pearson correlation PCA. Results of this analysis are presented in Figure 1 as a biplot of observation and variables from whole egg data (sum of yolk and albumen content) projected into 2-D plane of principal components F1 and F2. Dimension of 9 input variables was reduced to 4 principal components with eigenvalue >1 according to Kaiser`s criterion: F1 (32.75%) F2 (20.26%), F3 (17.98%) and F4 (11.86%). These components together carried 82.85% of variability. Best visual representation of PCA was obtained by 2-D factor plane of components F1 and F2. Components were correlated with original variables. Component F1 was mostly positively correlated by Mg, Fe, Zn. Component F2 positively with total lipid and proteins content, negatively with Ca. Relative clustering of observations is visible on Figure 1. There is obvious separation of egg samples from organic and free-range production, which are situated in left hemisphere of the graph with negative score for component F1. Observations from both cage systems are situated in the centre of graph and not completely differentiated which points to the fact, that overall composition of eggs from these two systems did not differentiated significantly. Another separate group was formed by observation of home-produced eggs in area of positive scores for F1. It is obvious, that even though univariate analysis by ANOVA did not provide clear picture of impact of hens housing systems on composition of eggs, it was possible to achieve classification using multivariate approach.

CONCLUSION

Results of this study confirmed the initial hypothesis and proved, that different approaches of laying hens housing can be significantly reflected in basic chemical composition of eggs. Statistical differences (p ≤0.05) were defined in 8 from 9 tested parameters. It was found that eggs from alternative production systems did not generally exhibit higher nutritional value than eggs from conventional cage facilities. In the case of total protein, whole conventional eggs contained highest average amount of 39.4 ±2.9% in comparison of 29.6 ±3.7% in organic eggs. Another significant differences (p <0.0001) were found in total lipid content. Organic eggs proved to be least fatty (43.3 ±3.9%), approximately 18% less than eggs from conventional cage production (52.5 ±1.2%). This was probably closely connected with limited free movement of lying hens in cage production. This system is also characteristic with diet based mainly of corn and soybean, which is rich on lipids. Another significant difference was found in elemental composition of eggs, specifically K, Mg, Na, Fe, P, Zn. Thanks to the combination of elemental composition and total lipid and protein content was possible to obtain clustering of observations by multivariate PCA. All tested groups of production systems were clearly separated, and it proved its important influence on chemical composition of eggs.

Important aspect of this work was comparison of presented results with other studies in this field. Common conclusion of all these studies is confirmation of significant effect of different housing systems on chemical composition and quality aspects of eggs. However, evaluation of influence of production systems, in many cases, differs considerably between studies and it was not possible to define general conclusions. For the unification of results will be necessary to expand research by more complex data about feed, climatic and other conditions and study the production in long term.

From the point of view of the consumers, these differences were in many cases negligible and the motivation to buy pricier alternative products should be still more driven by ethical and psychological aspects than desire for healthier and more nutritious product.

REFERENCES

Anderson, K. E. 2011. Comparison of fatty acid, cholesterol, and vitamin A and E composition in eggs from hens housed in conventional cage and range production facilities. *Poultry Science*, vol. 90, no. 7, p. 1600-1608. https://doi.org/10.3382/ps.2010-01289

Belitz, H., Grosch, W., Schieberle, P. 2009. *Food chemistry 4th revision and extended edition*. Berlin, Germany : Springer. 1070 p. ISBN 978-3-540-69933-0.

Bulková, V. 1999. *Nauka o poživatinách (Teaching about foodstuffs)*. Brno, Czech Republic : Institut pro další vzdělávání pracovníků ve zdravotnictví. 204 p. ISBN 80-701-3293-0. (In Czech)

Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens. Official Journal L 203, 03/08/1999 P. 0053-0057.

Filipiak–Florkiewicz, A., Dereń, K., Florkiewicz, A., Topolska, K., Juszczak, L., Cieślik, E. 2017. The quality of eggs (organic and nutraceutical vs. conventional) and their technological properties. *Poultry Science*, vol. 96, no. 7, p. 2480-2490. https://doi.org/10.3382/ps/pew488

Finglas, P. M., Roe, M. A., Pinchen, H. M., Berry, R., Church, S. M., Dodhia, S. K., Farron-Wilson, M., Swan, G. 2015. *McCance amd Widdowson`s the composition of foods, seventh summary edition*. Cambridge, UK : Royal society of chemistry, 630 p. ISBN 978-1-84973-636-7.

Geissler, C., Powers, H. 2010. *Human nutrition*. London, UK : Churchill livingstone, 792 p. ISBN 978-0-702-04463-2.

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, p. 1031-1038. https://doi.org/10.1016/j.foodchem.2007.07.019

Kralik, G., Škrtić, Z., Suchý, P., Straková, E., Gajčević, Z. 2008. Feeding Fish Oil and Linseed Oil to Laying Hens to Increase the n-3 PUFA in Egg Yolk. *Acta Veterinaria Brno*, vol. 77, no. 4, p. 561-568. https://doi.org/10.2754/avb200877040561

Küçükyılmaz, K., Bozkurt, M., Yamaner, Ç., Çınar, M., Çatlı, A. U., Konak, R. 2012. Effect of an organic and conventional rearing system on the mineral content of hen eggs. *Food Chemistry*, vol. 132, no. 2, p. 989-992. https://doi.org/10.1016/j.foodchem.2011.11.084

Lehninger, A. L., Nelson, D. L., Cox, M. M. 2013. *Lehninger principles of biochemistry*. 7th ed. New York, USA : W. H. Freeman, 1328 p. ISBN 10-1-4641-8795-9.

Lordelo, M., Fernandes, E., Bessa, R. J. B., Alves, S. P. 2016. Quality of eggs from different laying hen production systems, from indigenous breeds and specialty eggs. *Poultry Science*, vol. 6, no. 5, p. 728-730. https://doi.org/10.3382/ps/pew409

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

Minelli, G., Sirri, F., Folegatti, E., Meluzzi, A., Franchini, A. 2016. Egg quality traits of laying hens reared in organic and conventional systems. *Italian Journal of Animal Science*, vol. 6, no. 1, p. 728-730. https://doi.org/10.4081/ijas.2007.1s.728

Plazonić, I., Barbarić-Mikočević, Ž., Antonović, A. 2016. Chemical Composition of Straw as an Alternative Material to Wood Raw Material in Fibre Isolation. *Drvna industrija*, vol. 67, no. 2, p. 119-125. https://doi.org/10.5552/drind.2016.1446

Samman, S., Kung, F. P., Carter, L. M., Foster, M. J., Ahmad, Z. I., Phuyal, J. L., Petocz, P. 2009. Fatty acid composition of certified organic, conventional and omega-3 eggs. *Food Chemistry*, vol. 116, no. 4, p. 911-914. https://doi.org/10.1016/j.foodchem.2009.03.046

Schleenbecker, R., Hamm, U. 2013. Consumers' perception of organic product characteristics. A review. *Appetite*, vol. 71, p. 420-429. https://doi.org/10.1016/j.appet.2013.08.020

Shafie, F. A., Rennie, D. 2012. Consumer Perceptions Towards Organic Food. *Procedia - Social and Behavioral Sciences*, vol. 49, p. 360-367. https://doi.org/10.1016/j.sbspro.2012.07.034

WATT, 2018. Poultry trends 2018 [online]. Available at: www.polutrytrends.com/201811/index.php#/2.

Acknowledgments:

This work was supported by grant of specific research FCH-S-18-5334 and Material research centre at FCH BUT Sustainability and Development REG LO1211.

Contact address:

*Jaromír Pořízka, Brno University of Technology, Faculty of chemistry, Department of Food Chemistry and Biotechnology, Purkyňova 118, 612 00 Brno, Czech Republic, Tel.: +420776009591,
E-mail: porizka@fch.vut.cz
ORCID: https://orcid.org/0000-0002-2742-8053

Adam Mihalec, Brno University of Technology, Faculty of chemistry, Department of Food Chemistry and Biotechnology, Purkyňova 118, 612 00 Brno, Czech Republic,
E-mail: xcmichalec@fch.vut.cz

Pavel Diviš, Brno University of Technology, Faculty of chemistry, Department of Food Chemistry and Biotechnology, Purkyňova 118, 612 00 Brno, Czech Republic, Tel.: +420607915312,
E-mail: divis@fch.vut.cz
ORCID: https://orcid.org/0000-0001-6809-0506

Corresponding author: *