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The relationship between the physical and lipid characteristics of eggs from hens that were fed a diet supplemented with fat

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Abstract: The aim of this study was to investigate the potential correlations between certain physical and lipid characteristics of eggs from hens fed diets supplemented with three different types of fat. A six-week-last experiment was conducted on 45 Brown Lohman laying hens, 56 weeks of age. Animals were randomly divided into three groups of 15 and fed one of three experimental diets supplemented with either 3% of fish oil, palm olein, and lard. Samples of 10 eggs per group were collected at the start and at the end of the experiment to determine four physical and six lipid characteristics in boiled eggs. The supplementation of the hens' diet with fat at significantly affected the physical characteristics of the The biggest impact on such finding for total sample of investigated eggs had palm olein as a supplement in hen diet. Among the three investigated fat supplements, the addition of 3% lard to the laying hen diet resulted in the smallest total number of significant correlations between investigated physical and lipid traits. Comparing the end to the start of our experiment, supplementation of hen diet with fat decreases the number of correlations among egg physical and lipid characteristics, what can be considered as a positive result from both egg producer and consumer interests.

INTRODUCTION

Eggs are often considered a nutritional marvel due to their rich composition, encompassing around 40 proteins, among which are antihypertensive and bactericidal proteins. Additionally, eggs boast 18 different amino acids, including nine essential amino acids, stable amino acid composition, an optimal balance of saturated and unsaturated fatty acids, and the absence of carbohydrates or trans fats. As a result, eggs have gained recognition as a benchmark protein source for humans (Damaziak, Riedel, Gozdowski, et al., 2017), paralleling the biological value of breast milk (Molnar and Szollosi, 2020).

The global production of table eggs has surged by 24.4% in the past decade, reaching 76.7 million tons in 2018, with expectations of further growth owing to the escalating demand for animal-originated protein (Dilawar, Mun, Rathnayake, et al., 2021). Egg quality parameters play a pivotal role in the egg industry, influencing egg classification, pricing, consumer preferences, hatchability, chick weight, and overall quality (Kumar, Dahiya, Ratwan, et al., 2022). Egg quality in poultry is influenced by a variety of factors such as breed (genotype), age, health status, type of production system, number of birds per space (stocking density), diet, conditions of storage, and how long the eggs are stored.Previous studies have established connections between external and internal egg quality characteristics, with these relationships being influenced by factors such as the type of rearing system (Yang HM, Yang Z, Wang W, et al., 2014), the age and genotype of the hen, and nutritional considerations (Ahmadi and Rahimi, 2011). Furthermore, the environmental conditions of poultry facilities indirectly impact egg weight (Freitas, Tinoco, Baeta, et al., 2017). Lipid components in eggs are primarily concentrated in the egg yolk, with particular attention paid to the cholesterol content. Cholesterol, a vital component present in every cell of living organisms, plays a crucial role in cellular functions. The cholesterol level in eggs exhibits variability based on factors such as the species, breed, lines, and age of the animal (Yenilmez and Atay, 2023). Notably, consumer preferences can be influenced by the cholesterol content in egg yolks, leading to misconceptions and a potential reduction in egg consumption. This reduction poses a significant loss in terms of protein intake in human nutrition. Nutrition also plays a role in cholesterol deposition in egg yolks. Commercial layer diets often incorporate specific feedstuffs, such as vegetable oils rich in unsaturated fatty acids, to alter egg yolk lipid profile and decrease egg cholesterol content. Enhancing the nutritional quality of eggs from laying hens can be achieved by incorporating diverse fatty acid compositions into their diets. This approach holds promise as a valuable functional feed ingredient in poultry nutrition, aiming to produce eggs with enhanced functional food properties (Vlaicu PA, Panaite TD, Turcu RP, 2021). Balanced oil diets from various sources have demonstrated significant potential in enhancing the performance of laying hens and the quality of eggs (Gao, Zhang, Li et al., 2021), especially from the consumer's health perspective. Fatty acid composition and various microconstituents of added fats are the main factors affecting egg production and quality traits. Results from the literature on the potential impact of diet on egg cholesterol levels are inconsistent (Faitarone, Garcia, Roça, et al., 2013). Numerous researchers have reported that the inclusion of polyunsaturated fatty acid (PUFA)-rich oils in the diet leads to a reduction in egg cholesterol concentrations. However, other studies suggest that yolk cholesterol content remains constant, independent of dietary factors (Bertechini, 2003).

Taking into account all mentioned above, this study aimed to investigate possible correlations of some egg physical and lipid characteristics from hens fed a diet supplemented with three types of fat – fish oil, palm olein, and lard, which has significance to both egg producers and egg consumers. The investigated fats differ in their fatty acid composition and their utilization as a diet supplement in conventional egg production.

Table 1. Correlations of egg physical and lipid characeristics from hens fed diets supplemented with fish oil (n=10), palm olein (n=10) or lard (n=10) at the start and at the end of experimental feeding (total n=30)

Start End	**Egg weight (g)**	**Egg yolk weight (g)**	**Egg white weight (g)**	**Egg shell weight (g)**	**Egg total lipids (g/egg)**	**Egg TG (g/egg)**	**Egg TC (mg/egg)**	**Egg yolk total lipids (mg/g)**	**Egg yolk TG (mg/g)**	**Egg yolk TC (mg/g)**
Egg weight (g)	-	**r=0,666 P=0,000**	**r=0,971 P=0,000**	**r=0,646 P=0,000**	**r=0,624 P=0,000**	r=0,335 P=0,070	**r=0,437 P=0,016**	r=0,289 P=0,122	r=0,184 P=0,331	r=0,061 P=0,747
Egg yolk weight (g)	**r=0,486 P=0,007**	-	**r=0,506 P=0,004**	r=0,330 P=0,075	**r=0,802 P=0,000**	r=0,288 P=0,123	**r=0,401 P=0,028**	r=0,219 P=0,246	r=0,037 P=0,845	r= - 0,168 P=0,375
Egg white weight (g)	**r=0,938 P=0,000**	r=0,185 P=0,327	-	**r=0,550 P=0,002**	**r=0,533 P=0,002**	r=0,292 P=0,117	**r=0,400 P=0,029**	r=0,316 P=0,089	r=0,183 P=0,332	r=0,118 P=0,535
Egg shell weight (g)	**r=0,718 P=0,000**	r=0,312 P=0,094	**r=0,595 P=0,001**	-	r=0,220 P=0,243	r=0,288 P=0,123	r=0,289 P=0,121	r= -0,004 P=0,984	r=0,217 P=0,250	r=0,100 P=0,599
Egg total lipids (g/egg)	**r=0,404 P=0,027**	**r=0,887 P=0,000**	r=0,152 P=0,422	r=0,187 P=0,321	-	r=0,240 P=0,202	**r=0,403 P=0,027**	**r=0,757 P=0,000**	r=0,039 P=0,838	r= - 0,049 P=0,797
Egg TG (g/egg)	r=0,147 P=0,439	**r=0,398 P=0,029**	r=0,037 P=0,846	r= - 0,065 P=0,733	r=0,247 P=0,188	-	r= - 0,294 P=0,115	r=0,076 P=0,691	**r=0,966 P=0,000**	**r= - 0,480 P=0,007**
Egg TC (mg/egg)	r=0,293 P=0,116	r=0,353 P=0,056	r=0,186 P=0,326	r=0,297 P=0,111	r=0,352 P=0,056	r= -0,048 P=0,800	-	r=0,227 P=0,228	**r= - 0,394 P=0,031**	**r=0,834 P=0,000**
Egg yolk total lipids (mg/g)	r= -0,028 P=0,882	r=0,073 P=0,703	r= - 0,015 P=0,938	r= - 0,184 P=0,331	**r=0,524 P=0,003**	r= -0,163 P=0,338	r=0,119 P=0,532	-	r=0,022 P=0,906	r=0,110 P=0,561
Egg yolk TG (mg/g)	r= -0,068 P=0,723	r=0,027 P=0,888	r= - 0,070 P=0,712	r= - 0,214 P=0,257	r= - 0,075 P=0,694	**r=0,925 P=0,000**	r= 0,199 P=0,291	r= - 0,171 P=0,367	-	**r= - 0,437 P=0,016**
Egg yolk TC (mg/g)	r= -0,002 P=0,993	r= - 0,292 P=0,117	r=0,086 P=0,651	r=0,110 P=0,564	r= - 0,215 P=0,254	r= -0,301 P=0,107	**r=0,789 P=0,000**	r=0,085 P=0,657	r= - 0,212 P=0,262	-

r - the Pearson correlation coefficient
P<0,05 is considered statistically significant

EXPERIMENTAL

A six-week lasting experiment was conducted on 45 Brown Lohman laying hens, 56 weeks of age, and in the 34th week of production. Animals were randomly assigned to three groups of 15 birds each and fed one of three experimental diets supplemented with either 3% fish oil, palm olein, and lard. Samples of 10 eggs per group were collected at the start and at the end of the experiment to determine the following boiled egg physical characteristics: (egg weight (g), egg yolk weight (g), egg white weight (g), eggshell weight (g)), and lipid characteristics (egg total lipids (g/egg), egg triglycerides/egg TG (g/egg), egg total cholesterol/egg TC (mg/egg), egg yolk total lipids (mg/g), egg yolk triglycerides/egg/yolk TG (mg/g), egg yolk total cholesterol/egg yolk TC (mg/g)). Experimental design, the nutritional, chemical, and fatty-acid composition of experimental diets, as well as methods of preparation of egg and hard-boiled yolk and determination of egg physical and lipid characteristics, were in detail described and published in our earlier paper (Hodzic, Hamamdzic, Gagic, et al., 2008). Egg physical characteristics were determined by weighing. The preparation of eggs and yolk for laboratory processing was done according to Berrio and Hebert (1990), and the fat of the boiled egg yolk was extracted according to Folch, Lees, and Stanley (1957). The egg yolk total lipids were determined gravimetrically. Egg yolk TG was determined by the GPO-PAP method, using an enzymatic colorimetric assay with a lipid scavenging factor ("Human", Wiesbaden, Germany). Egg yolk TC was determined spectrophotometrically by the Liebermann-Burchard method with commercial tests ("Semikem", Sarajevo, B&H). Egg total lipids, egg TG, and egg TC were calculated from the respective yolk concentrations and weights.

To examine the relationship between the analyzed parameters, Pearson correlation coefficients (r) were calculated using Minitab statistical software (Minitab, Inc. 2014.). Results with P values less than 0,05 were considered statistically significant.

RESULTS AND DISCUSSION

The results are presented in Tables 1-4, and statistically significant results (P<0,05) are marked in bold.

Table 2. Correlations of egg physical and lipid characteristics from hens fed diet supplemented with fish oil at the start and at the end of experimental feeding (n=10)

Start **End**	**Egg weight (g)**	**Egg yolk weight (g)**	**Egg white weight (g)**	**Egg shell weight (g)**	**Egg total lipids (g/egg)**	**Egg TG (g/egg)**	**Egg TC (mg/egg)**	**Egg yolk total lipids (mg/g)**	**Egg yolk TG (mg/g)**	**Egg yolk TC (mg/g)**
Egg weight (g)	-	r=0,489 P=0,151	**r=0,975** **P=0,000**	r=0,611 P=0,060	r=0,539 P=0,108	r=0,367 P=0,297	r=0,413 P=0,236	r=0,395 P=0,259	r=0,218 P=0,544	r= - 0,214 P=0,554
Egg yolk weight (g)	r=0,477 P=0,163	-	r=0,299 P=0,401	r= - 0,002 P=0,995	**r=0,841** **P=0,002**	r=0,576 P=0,081	r=0,331 P=0,350	r=0,374 P=0,286	r=0,207 P=0,566	**r= - 0,745** **P=0,013**
Egg white weight (g)	**r=0,951** **P=0,000**	r=0,260 P=0,469	-	r=0,608 P=0,062	r=0,383 P=0,274	r=0,297 P=0,404	r=0,417 P=0,230	r=0,335 P=0,344	r=0,207 P=0,566	r= - 0,023 P=0,949
Egg shell weight (g)	r=0,574 P=0,083	r= - 0,118 P=0,746	r=0,537 P=0,110	-	r=0,210 P=0,560	r= -0,071 P=0,846	r= .0,136 P=0,707	r=0,333 P00,347	r= - 0,113 P=0,755	r= - 0,148 P=0,684
Egg total lipids (g/egg)	r=0,404 P=0,247	**r=0,830** **P=0,003**	r=0,315 P=0,376	r= - 0,361 P=0,306	-	**r=0,704** **P=0,023**	r=0,345 P=0,329	**r=0,815** **P=0,004**	r=0,438 P=0,205	r= - 0,587 P=0,075
Egg TG (g/egg)	r=0,395 P=0,259	r=0,542 P=0,105	r=0,418 P=0,229	r= - 0,248 P=0,490	r=0,631 P=0,050	-	r=0,295 P=0,408	r=0,617 P=0,058	**r=0,916** **P=0,000**	r= - 0,361 P=0,306
Egg TC (mg/egg)	**r=0,779** **P=0,008**	r=0,429 P=0,217	**r=0,799** **P=0,006**	r=0,404 P=0,247	r=0,584 P=0,076	r=0,443 P=0,200	-	r=0,263 P=0,462	r=0,218 P=0,544	r=0,378 P=0,281
Egg yolk total lipids (mg/g)	r=0,124 P=0,732	r=0,272 P=0,447	r=0,231 P=0,521	r= - 0,508 P=0,134	**r=0,760** **P=0,011**	r=0,493 P=0,148	r=0,497 P=0,144	-	r=0,564 P=0,089	r= - 0,191 P=0,597
Egg yolk TG (mg/g)	r=0,165 P=0,650	r=0,069 P=0,850	r=0,324 P=0,361	r= - 0,283 P=0,428	r=0,298 P=0,403	**r=0,873** **P=0,001**	r=0,270 P=0,451	r=0,476 P=0,165	-	r= - 0,051 P=0,888
Egg yolk TC (mg/g)	r=0,376 P=0,285	r= - 0,425 P=0,221	r=0,584 P=0,076	r=0,497 P=0,144	r= - 0,123 P=0,735	r= - 0,023 P=0,950	**r=0,635** **P=0,048**	r=0,268 P=0,454	r=0,210 P=0,561	-

r - the Pearson correlation coefficient

P<0,05 is considered statistically significant

Considering a total number of samples (n=30), and when laying hens were fed a diet without added fat – at the start of the experiment, 18 statistically significant correlations among investigated parameters were found (Table 1). At the end of the experiment, and after six weeks of feeding with dietary fat, the number of statistically significant correlations was 10 (Table 1). The number of statistically significant correlations among investigated egg parameters was higher at the end compared to the start of the experiment (7 vs 6) in the group of hens fed a diet supplemented with fish oil only (Table 2). A six-week lasting hen feeding with a diet supplemented with 3% palm olein resulted in the loss of statistically significant correlations of egg TC with other investigated physical and lipid parameters (Table 3). On the other hand, the addition of lard in hen diet had the biggest impact on egg total lipids (Table 4).Hen diet supplementation with investigated types of fats resulted in a few negative correlations among egg physical and lipid components, but none statistically significant. In general, a hen diet supplemented with fat significantly affected relationships among egg physical characteristics in our experimental design (Table 1). The most impact on such findings for a total sample of investigated eggs (Table 1) had palm olein as a supplement in hen diet (Table 3). In their study on 85-week-old laying hens, Inca, Martinez and Vilchez, (2020) identified statistically significant phenotypic correlations among external egg quality characteristics, including egg, yolk, albumen, and shell weight. Similarly, Mitrovic, Pandurevic, Milic, et al. (2010) observed statistically significant phenotypic correlation coefficients between egg weight and the weight of individual egg components. Notably, the study by Ketta and Tumova (2018) found that egg weight exhibited a significant increase as eggs became thicker. This suggests a potential relationship between increased egg weight and higher eggshell weight, which also demonstrated an increase in the eggshell thickness category. Comparing the end to the start of our experiment, it seems that supplementation of the hen diet with fat, regardless of the type of added fat, decreases the number of correlations among egg physical and lipid characteristics (Tables 1, 2, 3, and 4), and the smallest number of significant correlations among investigated egg parameters is found in diet supplemented with lard (Table 4).

Table 3. Correlations of egg physical and lipid characteristics from hens fed diet supplemented with palm olein at the start and at the end of experimental feeding (n=10)

Start End	**Egg weight (g)**	**Egg yolk weight (g)**	**Egg white weight (g)**	**Egg shell weight (g)**	**Egg total lipids (g/egg)**	**Egg TG (g/egg)**	**Egg TC (mg/egg)**	**Egg yolk total lipids (mg/g)**	**Egg yolk TG (mg/g)**	**Egg yolk TC (mg/g)**
Egg weight (g)	-	r=0,483 P=0,158	**r=0,979 P=0,000**	r=0,503 P=0,138	r=0,460 P=0,181	r= -0,075 P=0,836	**r=0,721 P=0,019**	r=0,192 P=0,594	r= - 0,252 P=0,482	r=0,559 P=0,093
Egg yolk weight (g)	**r=0,657 P=0,039**	-	r=0,403 P=0,248	r= - 0,152 P=0,675	**r=0,746 P=0,013**	r=0,468 P=0,173	r=0,223 P=0,536	r=0,105 P=0,772	r=0,167 P=0,646	r= - 0,123 P=0,735
Egg white weight (g)	**r=0,966 P=0,000**	r=0,440 P=0,193	-	r=0,392 P=0,262	r=0,409 P=0,240	r= -0,184 P=0,610	**r=0,672 P=0,033**	r=0,198 P=0,583	r= - 0,349 P=0,324	r=0,537 P=0,110
Egg shell weight (g)	**r=0,854 P=0,002**	r=0,418 P=0,229	**r=0,840 P=0,002**	-	r= - 0,082 P=0,823	r= -0,073 P=0,841	**r=0,648 P=0,043**	r=0,022 P=0,952	r= - 0,015 P=0,967	**r=0,706 P=0,022**
Egg total lipids (g/egg)	r=0,490 P=0,150	**r=0,944 P=0,000**	r=0,262 P=0,465	r=0,310 P=0,383	-	r=0,243 P=0,499	r=0,187 P=0,604	**r=0,740 P=0,014**	r=0,012 P=0,975	r= - 0,069 P=0,850
Egg TG (g/egg)	r=0,420 P=0,226	r=0,526 P=0,118	r=0,323 P=0,363	r=0,136 P=0,708	r=0,337 P=0,341	-	r= 0,276 P=0,440	r= - 0,109 P=0,765	**r=0,949 P=0,000**	r= - 0,446 P=0,197
Egg TC (mg/egg)	r=0,124 P=0,733	r=0,282 P=0,428	r=0,035 P=0,923	r=0,136 P=0,708	r=0,193 P=0,594	r=0,560 P=0,092	-	r=0,056 P=0,879	r= - 0,382 P=0,275	**r=0,940 P=0,000**
Egg yolk total lipids (mg/g)	r= -0,498 P=0,143	r= - 0,167 P=0,646	r= - 0,562 P=0,091	r= - 0,313 P=0,379	r=0,167 P=0,645	r= -0,509 P=0,133	r= 0,255 P=0,477	-	r= - 0,150 P=0,679	r=0,022 P=0,951
Egg yolk TG (mg/g)	r=0,140 P=0,700	r=0,126 P=0,728	r=0,119 P=0,744	r= - 0,063 P=0,864	r= - 0,054 P=0,883	**r=0,908 P=0,000**	r=0,523 P=0,121	r= - 0,469 P=0,172	-	r= - 0,449 P=0,193
Egg yolk TC (mg/g)	r= -0,357 P=0,312	r= - 0,435 P=0,209	r= - 0,299 P=0,401	r= - 0,171 P=0,637	r= - 0,479 P=0,161	r=0,173 P=0,633	**r=0,737 P=0,015**	r= - 0,112 P=0,759	r=0,425 P=0,221	-

r - the Pearson correlation coefficient
P<0,05 is considered statistically significant

Actually, at the start of the experiment, there were several significant correlations among different egg and egg yolk physical and lipid characteristics, while at the end of the experiment, the only consistent and significantly positive correlation among egg physical and lipid characteristics was this one between egg total lipids and egg yolk weight found in all tested groups as well as in the total sample of eggs. In the study by Inca et al. (2020), it was observed that phenotypic correlations between egg quality characteristics in older laying hens remained unaffected by yolk quality characteristics. Similarly, Shafey (1996) found that changes in the proportion of egg components associated with egg size did not have an impact on yolk lipid and fatty acid concentrations. Interestingly, within a specific age group, no significant differences were noted in yolk lipid and fatty acid concentrations. Shafey (1996) also reported that egg yolk lipid produced by 1-year-old hens exhibited 2.5% lower lipid and 4.3% higher linoleic acid (LA) concentrations compared to those produced by 6-month-old hens. The reduction in yolk total lipid and the increase in the unsaturated fatty acid, LA, along with a decrease in saturated fatty acids in eggs from older hens, may be of interest to consumers. However, Fennema (1993) proposes that variations in total yolk lipid content are more influenced by bird genetic strain than diet.Significant positive correlations between the same egg and egg yolk lipid components are expected, taking into account that egg lipid components are mainly contained in egg yolk. The only one such significant correlation was lacking – between egg and egg yolk total lipid, and when palm olein (Table 3) and lard (Table 4) were added to hen diets. Considering egg/egg yolk cholesterol as the most interesting lipid parameter, the only significant correlation we found between egg TC and egg weight was when hens were fed a diet supplemented with fish oil rich in PUFAs (Table 2). Excessive energy intake, surpassing maintenance and production requirements, leads to increased body weight and cholesterol synthesis. Consequently, an excess of cholesterol may be transferred to the egg yolk (Faitarone et al., 2013). In Cornell random-bred Leghorn (LC) and Athens-Canadian random-bred (AC) hen populations, correlations between yolk cholesterol concentration and other egg traits, such as proportions of the egg, percentage yolk dry matter, and percentage yolk fat, were found to be low (Washburn and Marks, 1985), consistent with our study.

Table 4. Correlations of physical and lipid characteristics from hens fed diet supplemented with lard at the start and at the end of experimental feeding (n=10)

Start End	**Egg weight (g)**	**Egg yolk weight (g)**	**Egg white weight (g)**	**Egg shell weight (g)**	**Egg total lipids (g/egg)**	**Egg TG (g/egg)**	**Egg TC (mg/egg)**	**Egg yolk total lipids (mg/g)**	**Egg yolk TG (mg/g)**	**Egg yolk TC (mg/g)**
Egg weight (g)	-	**r=0,901 P=0,000**	**r=0,978 P=0,000**	**r=0,846 P=0,002**	**r=0,885 P=0,001**	r=0,606 P=0,063	r=0,558 P=0,093	r=0,153 P=0,673	r=0,392 P=0,263	r= - 0,137 P=0,706
Egg yolk weight (g)	r=0,036 P=0,922	-	**r=0,806 P=0,005**	**r=0,844 P=0,002**	**r=0,864 P=0,001**	r=0,377 P=0,283	**r=0,699 P=0,024**	r= - 0,065 P=0,858	r=0,107 P=0,768	r= - 0,037 P=0,919
Egg white weight (g)	**r=0,891 P=0,001**	r= - 0,408 P=0,241	-	**r=0,742 P=0,014**	**r=0,855 P=0,002**	r=0,620 P=0,056	r=0,455 P=0,186	r=0,262 P=0,465	r=0,440 P=0,203	r= - 0,181 P=0,617
Egg shell weight (g)	**r=0,680 P=0,031**	r=0,393 P=0,261	r=0,372 P=0,289	-	**r=0,687 P=0,028**	r=0,611 P=0,061	r=0,605 P=0,064	r= - 0,133 P=0,714	r=0,403 P=0,248	r= - 0,034 P=0,926
Egg total lipids (g/egg)	r=0,103 P=0,777	**r=0,906 P=0,000**	r= - 0,302 P=0,397	r=0,397 P=0,257	-	r=0,446 P=0,197	r=0,382 P=0,277	r=0,445 P=0,197	r=0,213 P=0,556	r= - 0,339 P=0,338
Egg TG (g/egg)	r= -0,113 P=0,756	r=0,504 P=0,137	r= - 0,345 P=0,329	r=0,159 P=0,660	r=0,382 P=0,277	-	r=0,185 P=0,609	r=0,185 P=0,608	**r=0,960 P=0,000**	r= - 0,112 P=0,758
Egg TC (mg/egg)	r= -0,095 P=0,794	r=0,409 P=0,240	r= - 0,256 P=0,475	r=0,037 P=0,919	r=0,124 P=0,732	r= -0,089 P=0,806	-	r= - 0,476 P=0,164	r= - 0,002 P=0,996	**r=0,686 P=0,028**
Egg yolk total lipids (mg/g)	r=0,135 P=0,711	r= - 0,034 P=0,926	r=0,146 P=0,687	r=0,064 P=0,861	r=0,393 P=0,261	r= -0,182 P=0,615	r= 0,593 P=0,071	-	r=0,201 P=0,578	r= - 0,595 P=0,069
Egg yolk TG (mg/g)	r= - ,132 P=0,717	r=0,081 P=0,825	r= - 0,177 P=0,625	r= - 0,012 P=0,973	r= - 0,006 P=0,987	**r=0,901 P=0,000**	r= 0,314 P=0,377	r= - 0,175 P=0,629	-	r= - 0,098 P=0,787
Egg yolk TC (mg/g)	r= -0,097 P=0,790	r= - 0,418 P=0,229	r=0,104 P=0,775	r= - 0,261 P=0,466	r= - 0,630 P=0,051	r= -0,510 P=0,132	**r=0,657 P=0,039**	r= - 0,578 P=0,080	r= - 0,385 P=0,272	-

r - the Pearson correlation coefficient
P<0,05 is considered statistically significant

Despite supplementing layer diets with vegetable oils rich in PUFAs, such as rapeseed, canola and soybean oils, at various levels in commercial diets, there were no significant changes observed in the nutritional composition of egg yolks. Additionally, the inclusion of these PUFAs did not result in reduction in yolk cholesterol content (Faitarone et al., 2013). According to Bertechini (2003), chickens can produce 10 times more cholesterol per kilogram of liver compared to humans. Consequently, manipulating layer diets to decrease egg cholesterol levels is not highly effective, as chickens can maintain the egg cholesterol levels that are considered essential for egg composition. Yolk cholesterol concentration exhibits resistance to change due to the required level of yolk cholesterol level essential for embryo development (Shafey and Cham, 1994). However, hens can adjust yolk PUFAs content in response to dietary lipid sources.
This capability stems from the fact that, unlike mammals, poultry absorb dietary fat through the portal system as portomicrons, directly entering the bloodstream and being transported to the liver – the primary site of lipogenesis - allowing for direct fat absorption by the liver (Hodzic, Hamamdzic, Gagic, et al, 2012).

CONCLUSION

Among the three investigated fat supplements, the addition of 3% lard to the laying hen diet resulted in the smallest total number of significant correlations between investigated physical and lipid traits. Moreover, lard supplementation also resulted in the biggest decrease in statistically significant correlations at the end of the experiment. In general, comparing the end to the start of our experiment, supplementation of hen diet with fat decreases the number of correlations among egg physical and lipid characteristics, which can be considered as a positive result for both egg producer and consumer interests.

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Summary/Sažetak

Cilj ovog istraživanja je bio istražiti moguće korelacije pojedinih fizičkih i lipidnih karakteristika jaja kokoši hranjenih sa tri vrste masti – ribljim uljem, palminim oleinom i svinjskom mašću, što ima značaja kako za proizvođače tako i za potrošače jaja. Eksperiment u trajanju od šest sedmica je proveden na 45 kokoši nosilja Brown Lohman, starosti 56 sedmica, odnosno u 34. sedmici proizvodnje. Životinje su nasumično raspoređene u tri grupe od po 15 ptica i hranjene jednom od tri eksperimentalne smješe sa dodatkom 3% ribljeg ulja, palminog oleina ili svinjske masti. Uzorci od po 10 jaja po grupi prikupljani su na početku i na kraju eksperimenta kako bi se odredile fizičke karakteristike jaja (težina jaja, težina žumanjka, težina bjelanjka, težina ljuske jajeta) i lipidne komponente (ukupni lipidi jajeta, trigliceridi jajeta, ukupni holesterol jajeta, ukupni lipidi žumanjka, trigliceridi žumanjka, ukupni holesterol žumanjka).

Ishrana kokoši s dodatkom masti značajno je utjecala na fizičke karakteristike jaja. Najveći utjecaj na takav nalaz ukupnog uzorka ispitivanih jaja imao je palmin olein kao dodatak u hrani kokoši. Upoređujući kraj i početak našeg eksperimenta, čini se da dodavanje masti u hranu kokoši, bez obzira na vrstu dodane masti, smanjuje broj korelacija između fizičkih i lipidnih karakteristika jaja, što se može smatrati pozitivnim nalazom i za proizvođače i za potrošače jaja.