



The Use of Different Fat Sources on Performance, Egg Quality and Egg Yolk Fatty Acids Content in Laying Quails

Rabia Göçmen^{1,a,*}, Gülşah Kanbur^{1,b}, Yusuf Cufadar^{1,c}

¹Department of Animal Science, Agriculture Faculty, Selçuk University, Selçuklu, 42130 Konya, Turkey.

*Corresponding author

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ABSTRACT

In this study, the performance, egg quality, egg yolk colour and fatty acids profile of quails fed on diets containing different fat sources were determined. During 8 weeks trial, a total of 75, 10-week-old laying quails were used. Three diets were formulated to contain soybean oil (SBO), sunflower oil (SFO) and hempseed oil (HSO), respectively. The performance parameters were not significantly influenced by the dietary different oil sources. Eggshell ratio, eggshell thickness, eggshell breaking strength, egg shape index, egg yolk index, albumen index and egg yolk colour values (except a^*) were not influenced by the different dietary oil sources. The a^* value was significantly affected and the highest a^* value was the HSO of group. The different oil sources supplementation to the diets was effective on fatty acid composition of the egg yolk. The highest value in terms of α -linolenic acid, total polyunsaturated fatty acids and total n-3 fatty acids were found in the diet fed group with HSO added. As a result; supplementation of different sources of oil to quail diets without negatively affecting performance and egg quality can be used to change the egg yolk fatty acid composition. Hempseed oil may increase the amount of total polyunsaturated fatty acids and total n-3 fatty acid content of egg yolk.

^a rabiacaar@selcuk.edu.tr

^b <http://orcid.org/0000-0001-9816-7746>

^c gkanbur@selcuk.edu.tr

<http://orcid.org/0000-0002-6254-2257>

^c ycufadar@selcuk.edu.tr

<http://orcid.org/0000-0001-9606-791X>



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Introduction

Essential fatty acids, which are called polyunsaturated fatty acids (PUFA) that cannot be produced by the body and must be included in the diet, are essential for maintaining optimum health. There are two classes of PUFA as n-6 and n-3 (Singh, 2005). It is recognized that n-3 PUFA are useful for optimum human health. The three major n-3 PUFA are α -linolenic acid (ALA), docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). Most of the positive effects on health are more bound up with EPA and DHA (Trautwein, 2001). Long-chain metabolites in the form of precursors have effect on systems such as neurotransmitter, immune, and blood flow rate to the brain (Das, 2006). Egg consumption is widespread in the world as there is no religious or cultural restriction. Many people in some Asian countries prefer quail eggs. It has been reported that the nutritional value of quail eggs is higher than other eggs and is very rich in antioxidants, minerals and vitamins (Lalwani, 2012). Tunsaringkarn et al. (2013) reported that the crude oil amount of quail eggs 9.89%. The lipids in the feed almost never affect the saturated and monounsaturated fatty acid

amount of the egg (Van Elswyk et al., 1995; Herber and Van Elswyk, 1996; Baucells et al., 2000; Cachaldora et al., 2008). However, the amount and profile of egg PUFA can be changed by dietary lipids modification. There have been many studies on the addition of seeds and oil high in alpha linolenic acid and fish oil high in EPA / DHA to chicken diets. Plants such as canola, soybean, walnut and flaxseed are rich in ALA (Harris et al., 2009). The plant rich in linoleic acid (LA) are sunflower seed (da Silva Filardi et al., 2005). Hemp seed oil's fatty acid profile and n-6 / n-3 ratio is 3/1 such as flaxseed. For this reason, hemp seed oil may be advantageous in feeding studies (Deferne and Pate, 1996). The major fatty acids of hempseed oil are linoleic (60%) and ALA (19%) acids and its total polyunsaturated fatty acids ratio is around 75 - 80% (Callaway, 2004; House et al., 2010). A positive change in the fatty acid composition of quail eggs (especially the n3 / n6 ratio) can make it a much healthier food for human nutrition. In this study, the use of different plant-base oil in diets on laying performance, egg quality and egg yolk fatty acids content were determined.

Material and Methods

A total of 75, 10 - weeks - old laying quails (*Coturnixcoturnix japonica*) were used in this research. The laying quails were divided into 3 treatment groups with 5 replicates (5 quails, each). The laying quails were reared in 33 × 40 × 28 cm size cages under the semi-controlled periphery terms (ventilation controlling system) with a 16-h light - 8 h dark illumination period. Quails were provided with feed and water *ad-libitum* for 8 weeks experimental period. Quails were experimental diets that were formulated to meet the nutrient requirements of National Research Council (Council, 1994) (Table 1). Hemp seeds were provided by a local supplier. The seeds were pressed in a cold press machine (Karaerler Machine, NF 100 model, Ankara) at 45-50°C and HSO was obtained by removing hempseed meal. Three diets were formulated to contain soybean oil (SBO), sunflower oil (SFO) and hemp seed oil (HSO) at 6.2%. All treatment diets were adjusted as to be isocaloric and isonitrogenic. The fatty acid composition of the plant base oils used in the experimental diets is given in Table 2.

Quails were weighed at the first and the end of the last day of the trial and the body weight changes were determined. Feed intake, egg production, egg mass, feed conversion ratio (feed intake(g)/egg mass(g)) was determined at the end of the experiment 4th and 8th weeks.

The average egg percentage (%) was detected with the formula of the (total eggs/ total quail) × 100. Egg mass was determined from the ratio of egg production (%) to egg weight (g). A total of 240 eggs (80 eggs for each group) were collected in the last two days of each 14 days. Egg samples were selected randomly from each sub-group and weighed and then determined to have eggshell breaking strength, eggshell thickness, eggshell weight, egg shape index, egg yolk index and albumen index. Egg yolk height and albumen height were determined by digital height caliper. Egg yolk diameter, egg and egg albumen length and width were determined by a digital calliper (Mitutoyo Inc., Japan). Egg shape (Anderson et al., 2004), egg yolk index and albumen index (Romanoff and Romanoff, 1949) were computed by

following formulas respectively; $[\text{Egg width/ Egg length}] \times 100$, $[(\text{yolk height/yolk diameter}) \times 100]$, $[(\text{albumen height/ (average albumen length and width)}) \times 100]$. Eggshell breaking strength was measured using the compression test module and resistance of eggshell broad pole to pressure was determined (Orka Food Technology Ltd., Ramat Hasharon, Israel). The cracked eggshells were washed and dried, then weighed using a 0.01 g precision scale. Eggshell weight ratio was calculated using the formula: $\text{Eggshell weight (\%)} = [\text{eggshell weight (g)/egg weight (g)}]/100$. The thickness of the eggshell (with membrane) was determined as the average of the measurements made from the blunt end with two points on the equatorial axis of the egg using a micrometre (Mitutoyo Inc., Japan). The yolk color was determined using Minolta CR-410 colorimeter (Konica Minolta, Osaka, Japan). Fatty acid profile of a total of 90 egg yolk (30 eggs for each group) was detected and oils were extracted by the solvent method (Ethanol/chloroform solvent) (Kovalcuks and Duma, 2014). Fatty acid methyl esters of the egg yolk oils were obtained according to the method of the recommendation of the European Union (EU) regulation 2568/91 (Regulation, 1991). Egg yolk oils were weighed (0.10 g) into the screw-cap glass tubes and dissolved within 10.0 mL hexane. Following, 100 µL 2N potassium hydroxide solution in the methanol was added to the tubes and shaken vigorously for 30 s. The tubes were centrifuged at 2500 × g for 5 min and the upper layer was taken to a small vial and stored at 0°C till analysing date (Ayyildiz et al., 2015). The fatty acid composition was detected by gas chromatography (GC) device (Shimadzu GC-2010 Plus, Japan) which had the FID detector and HP-88 column (100m × 250 µm × 0.20 µm id). The temperature at the injection block was 250°C and the column oven heat program was adjusted as 2 min at 50°C, 4 min between 50°C -250°C, and 10 min at 250°C. The carrier gas was Helium with 1.3 mL/min flow rate. Fatty acids were detected by using retention time (min) and area (%) data of identified peaks and classed with standards of fatty acids and were presented as a percentage.

Table 1. Nutrient composition of experimental diets

Ingredients	Soybean oil	Sunflower oil	Hempseed oil
Corn	50.10	50.10	50.10
Soybean meal (45% CP)	36.00	36.00	36.00
Soybean oil	6.20	-	-
Sunflower oil	-	6.20	-
Hempseed oil	-	-	6.20
Limestone	5.10	5.10	5.10
Dicalcium phosphate	1.80	1.80	1.80
Salt	0.25	0.25	0.25
Premix ¹	0.25	0.25	0.25
L-Lysine	0.10	0.10	0.10
DL-Methionine	0.20	0.20	0.20
Calculated nutrients			
Crude protein, %	20.01	20.01	20.01
Metabolizable energy, kcal ME/kg	2904	2904	2904
Calcium, %	2.50	2.50	2.50
Available phosphorus, %	0.35	0.35	0.35
Lysine, %	1.05	1.05	1.05
Methionine, %	0.48	0.48	0.48
Methionine + Cystine, %	0.84	0.84	0.84

¹: Premix provided the following per kg of diet: retinyl acetate, 4.0 mg; cholecalciferol, 0.055 mg; DL- α-tocopheryl acetate, 11 mg; nicotinic acid, 44 mg; calcium-D-pantothenate, 8.8 mg; riboflavin sodium phosphate, 5.8 mg; thiamine hydrochloride, 2.8 mg; cyanocobalamin, 0.66 mg; folic acid, 1 mg; biotin, 0.11 mg; choline, 220 mg; Mn, 60 mg; Fe, 30 mg; Cu, 5 mg; I, 1.1 mg; Se, 0.1 mg

Table 2. The fatty acid composition of dietary different plant-base oil sources

Fatty acids	Soybean oil	Sunflower oil	Hempseed oil
Palmitic acid (16:0)	7.47	7.09	7.70
Stearic acid (18:0)	3.00	3.98	3.55
Oleic acid (18:1)	17.09	25.80	17.14
Linoleic acid (18:2)	56.19	63.14	55.22
α -Linolenic acid (18:3, n3)	15.79	0.00	15.89
Arachidic acid (20:0)	0.45	0.00	0.87
Σ SFA	10.92	11.07	12.12
Σ MUFA	17.09	25.80	17.14
Σ PUFA	71.98	63.14	71.11
Σ n-3	15.79	0.00	15.89
Σ n-6	56.19	63.14	55.22

Table 3. Effect of different fat sources to the diets on performance in laying quails

Parameters	Soybean oil	Sunflower oil	Hemp seed oil	SEM
Initial body weight, g	241.75	233.20	235.55	13.14
Final body weight, g,	258.94	256.20	271.70	14.90
Body weight change, g	17.19	23.00	36.10	16.48
Egg production, %	92.05	90.00	91.70	3.77
Feed intake, g	26.77	27.20	28.85	1.27
Feed conversion ratio, (Feed/Egg mass)	2.29	2.32	2.40	0.12
Egg weight, g	12.72	13.07	13.14	0.42
Egg mass, g	11.71	11.76	12.04	0.57

SEM: Pooled standard error of means

The trial was designed as a complete randomized model and data were analysed by using the ANOVA procedure with Minitab (Minitab, 2000). Duncan's multiple range test was used to determine the differences among treatments which found significantly different ($P < 0.05$).

Results and Discussion

The effects of use of different fat sources in the diet on performance parameters in laying quails are given in Table 3. The use of different fats in quail rations did not significantly affect body weight, feed consumption, feed utilization, egg yield, egg weight and egg mass ($P > 0.05$).

Adding oils to the diets is done to meet the energy needs economically. The fact that there was not difference in body weight between the groups indicates that the treatments did not have a negative effect and the energy needs were met. It has been reported that the addition of 4% different fat sources to laying quail rations did not affect the number of eggs after 10 weeks experiment (Güçlü et al., 2008). Gakhar et al. (2012) reported that the addition of the hemp products, hemp seed or hempseed oil in the diets of laying hens up to a maximum level of 20 and 12% did not deteriorated the performance. The addition of n-3 PUFA to the diet of the quails did not negatively affect the body weight, feed consumption and feed efficiency (Ebeid et al., 2011). Fébel et al. (2008) found that supplementation of different sources of oil (sunflower and lard) to broiler diets did not affect growth performance. It has been reported that the addition of soybean, rapeseed and linseed oil to the laying hens diet for 12 weeks did not affect egg production, egg weight and body weight (Ceylan et al., 2011). Balevi and Coskun (2000) reported that the addition of 9 different dietary fat sources to laying hen did not affect egg production, egg size and feed intake. These studies are consistent with our results. However, there are studies with different conclusions such as Yin et al. (2008)

reported that the body weight and body weight gain of quails was improved via dietary supplementation of sunflower and soybean oil for 12 weeks. Adding sunflower and canola oil to broiler diets improved growth performance and feed efficiency (Nobakht et al., 2011). Jalali et al. (2015) found that the addition of soybean oil positively affected the growth performance and feed efficiency in broilers. While most studies investigating the addition of PUFA-rich oils to poultry diets reported positive effects on body weight, body weight gain and feed efficiency, almost no adverse effects were noted (Alagawany et al., 2019).

The effects of different plant base oil sources on egg quality and egg yolk colour value are shown in Table 4.

The addition of different plant-based oil sources to quail diets did not significantly affect egg quality parameters ($P > 0.05$). While the a^* value was significantly affected in egg yolk color values, the highest value was recorded in the HSO group. The tocopherol content of hemp seed oil is higher than soybean oil and sunflower oil (Ghazani and Marangoni, 2013). This is probably the reason why the egg yolk a^* value of the HSO group was higher than the other groups.

Ceylan et al. (2011) found that egg quality did not affect the supplementation of different dietary oil sources to the laying hen diets. Güçlü et al. (2008) reported that different oil sources did not affect egg albumen index and eggshell thickness. It was found that the addition of different oil sources did not affect egg quality (Grobass et al., 2001; Bozkurt et al., 2012; Bertipaglia et al., 2016). Reda et al. (2020) concluded that the addition of different oil sources to the diets of laying quail did not affect egg quality (except egg yolk index). Our results are in agreement with the literature.

The effect of diets containing different plant-based oils in laying quail on egg yolk fatty acid profile is presented in Table 5.

Table 4. Effect of different fat sources to the diets on egg quality in laying quails

Parameters	Soybean oil	Sunflower oil	Hempseed oil	SEM
Eggshell weight ratio, %	8.38	8.03	7.92	0.24
Eggshell thickness, mm	0.346	0.349	0.348	0.01
Eggshell breaking strength, kg	1.59	1.55	1.50	0.09
Egg shape index	78.07	78.19	78.49	1.32
Egg yolk index	43.03	44.55	44.06	1.08
Albumen index	9.26	9.83	9.37	0.53
Egg Yolk Colour Value				
<i>L</i> *	52.66	53.73	52.98	1.18
<i>a</i> *	11.47 ^b	10.60 ^b	13.20 ^a	1.01
<i>b</i> *	40.70	40.07	41.63	1.41

^{a,b}: Differences between the averages are significant in the same column with different letter (P<0.05). SEM: Pooled standard error of means.

Table 5. Effect of different fat sources to the diets on egg yolk fatty acids content in laying quails

Egg yolk fatty acids	Soybean oil	Sunflower oil	Hempseed oil	SEM
Myristic acid (14:0)	0.351	0.355	0.324	0.024
Palmitic acid (16:0)	23.031	23.296	22.271	0.733
Palmitoleic acid (16:1)	3.758	2.770	3.099	0.540
Stearic acid (18:0)	8.770	9.398	9.885	0.535
Oleic acid (18:1)	40.566 ^{ab}	42.178 ^a	37.270 ^b	1.623
Linoleic acid (18:2)	17.680	17.583	21.140	1.860
α -Linolenic acid (18:3, n3)	1.792 ^b	0.00 ^c	2.280 ^a	0.320
Arachidic acid (20:0)	0.441	0.551	0.458	0.048
Eicosapentaenoic acid (EPA; 20:5)	0.080 ^b	0.019 ^c	0.125 ^a	0.009
Erucic acid (22:1)	1.965	2.134	1.880	0.122
Docosahexaenoic acid (DHA; 22:6)	0.204 ^a	0.053 ^b	0.219 ^a	0.027
Σ SFA	32.593	33.600	32.939	0.497
Σ MUFA	46.30 ^{ab}	47.631 ^a	42.27 ^b	2.047
Σ PUFA	19.83 ^{ab}	17.75 ^b	24.20 ^a	2.135
Σ n-3	1.996 ^b	0.052 ^c	2.847 ^a	0.302

^{a,b,c}: Differences between the averages are significant in the same line with different letter (P<0.05). SEM: Pooled standard error of means.

The SFO group's Σ MUFA content was significantly higher than the other groups (P<0.05). The highest oleic acid content was in the SFO group, and the difference among the groups was found to be significant (P<0.05). The group with the highest content of α -linolenic acid (ALA), EPA, DHA, Σ PUFA and n-3 fatty acids was HSO (P<0.05).

The result of the current study showed that dietary different plant-based oil sources addition altered the fatty acid profile of egg yolk in quails. da Silva Filardi et al. (2005) reported that adding different sources of oil to laying hen diets changed the egg fatty acid composition, adding oil to canola lowered linoleic acid and increased ALA and DHA content. The addition of two different levels (1.5% and 3%) and 4 different oil sources (sunflower oil, fish oil, linseed and rapeseed oil) to the laying hen diets increased the linolenic acid content of the egg yolk in 3% linseed and rapeseed oil groups (Ceylan et al., 2011). It has been reported that the egg yolk fatty acid profile can be changed as desired by using marine or oilseed (Van Elswyk, 1997; Milinsk et al., 2003; Cachaldora et al., 2006). The fatty acid DHA is gained in eggs in two ways. It may be taken directly by diet or synthesized from α -linolenic acid (Yalçın and Ünal, 2010).

Eggs are not rich in n-3 PUFAs, but changes to diet can increase the n-3 fatty acid content of eggs (Ferrier et al., 1995). Eggs enriched in n-3 fatty acids are extremely beneficial for human health (Fraeye et al., 2012; Laudadio et al., 2015). An important biological role of ALA is that it serves as a substrate for the synthesis of EPA and DHA (Burdge, 2004).

Hemp seeds contain approximately 35% oil (Sapino et al., 2005). Hempseed oil has a high PUFA concentration and the

main free fatty acids are ALA and γ -linolenic acid (GLA) (Liang et al., 2015). Gakhar et al. (2012) reported that the addition of hemp seeds and hempseed oil to 20% and 12% levels in laying hen diets increased the n-3 fatty acid content of egg yolk without adversely affecting performance. Research has shown that HSM (hempseed meal) in laying hens diet increases the amount of n-3 fatty acids found in eggs (Silversides and Lefrancois, 2005; Nejlat et al., 2014).

Conclusion

According to the results of this study, the addition of different plant-based oil sources to laying quail diets did not induce any negative effects on body weight, egg production, feed intake, feed conversion ratio, egg weight, egg mass and egg quality. The *a** value was significantly affected in egg yolk color values, the highest value was recorded in the HSO group. The different plant-based oil sources supplementation to the diets was effective on fatty acid composition and total monounsaturated fatty acids and total polyunsaturated fatty acids content of the egg yolk. The highest value in terms of α -linolenic acid, total polyunsaturated fatty acids and total omega-3 fatty acids were found in the diet fed group with hempseed oil added. These results showed that hempseed oil can be used as an alternative to soybean oil and sunflower oil to change the fatty acid profile of the egg yolk, especially to increase the n-3 fatty acid content. There is a need for more research on this subject.

References

- Alagawany M, Elnesr SS, Farag MR, El-Hack A, Mohamed E, Khafaga AF, Taha AE, Tiwari R, Yatoo M, Bhatt P. 2019. Omega-3 and Omega-6 fatty acids in poultry nutrition: effect on production performance and health. *Animals*, 9: 573
- Anderson K, Tharrington J, Curtis P, Jones F. 2004. Shell characteristics of eggs from historic strains of single comb white leghorn chickens and the relationship of egg shape to shell strength. *International Journal of Poultry Science*, 3: 17-19
- Ayyildiz HF, Topkafa M, Kara H, Sherazi STH. 2015. Evaluation of fatty acid composition, tocopherol profile, and oxidative stability of some fully refined edible oils. *International Journal of Food Properties*, 18: 2064-2076
- Balevi T, Coskun B. 2000. Effects of some dietary oils on performance and fatty acid composition of eggs in layers. *Revue de Médecine Vétérinaire*, 151: 847-854
- Baucells M, Crespo N, Barroeta A, Lopez-Ferrer S, Grashorn, MA. 2000. Incorporation of different polyunsaturated fatty acids into eggs. *Poultry Science*, 79: 51-59
- Bertipaglia LA, Sakamoto MI, Bertipaglia LMA, Melo GMPd. 2016. Lipid sources in diets for egg-laying Japanese quail: performance and egg quality. *Acta Scientiarum. Animal Sciences*, 38: 281-284
- Bozkurt M, Küçükylmaz K, Catli A, Çınar M, Bintaş E, Çöven F. 2012. Performance, egg quality, and immune response of laying hens fed diets supplemented with mannan-oligosaccharide or an essential oil mixture under moderate and hot environmental conditions. *Poultry Science*, 91: 1379-1386
- Burdge G. 2004. α -Linolenic acid metabolism in men and women: nutritional and biological implications. *Current Opinion in Clinical Nutrition & Metabolic Care*, 7: 137-144
- Cachaldora P, García-Rebollar P, Alvarez C, Blas JD, Méndez J. 2006. Effect of type and level of fish oil supplementation on yolk fat composition and n-3 fatty acids retention efficiency in laying hens. *British Poultry Science*, 47: 43-49
- Cachaldora P, Garcia-Rebollar P, Alvarez C, De Blas J, Méndez 2008. Effect of type and level of basal fat and level of fish oil supplementation on yolk fat composition and n-3 fatty acids deposition efficiency in laying hens. *Animal feed science and technology*, 141: 104-114
- Callaway J. 2004. Hempseed as a nutritional resource: An overview. *Euphytica*, 140: 65-72
- Ceylan N, Ciftçi I, Mizrak C, Kahraman Z, Efil H. 2011. Influence of different dietary oil sources on performance and fatty acid profile of egg yolk in laying hens. *Journal of Animal and Feed Sciences*, 20: 71-83
- Council NR. 1994. Nutrient requirements of poultry. Washington, DC, National Academic Press). ORTIZ, LT, REBOLÉ, A., ALZUETA, C, RODRÍGUEZ, ML & TREVIÑO, J. (2001) Metabolizable energy value and digestibility of fat and fatty acids in linseed determined with growing broiler chickens. *Br. Poultry Sci*, 42: 57-63
- Da Silva Filardi R, Junqueira O, De Laurentiz A, Casartelli E, Rodrigues EA, Araujo LF. 2005. Influence of different fat sources on the performance, egg quality, and lipid profile of egg yolks of commercial layers in the second laying cycle. *Journal of Applied Poultry Research*, 14: 258-264
- Das UN. 2006. Essential fatty acids-a review. *Current pharmaceutical biotechnology*, 7: 467-482
- Deferne JL, Pate DW. 1996. Hemp seed oil: A source of valuable essential fatty acids. *J Int Hemp Assoc*, 3: 1-7
- Ebeid T, Fayoud A, El-Soud S, Eid Y, El-Habbak M. 2011. The effect of omega-3 enriched meat production on lipid peroxidation, antioxidative status, immune response and tibia bone characteristics in Japanese quail. *Czech Journal of Animal Science*, 56: 314-324
- Fébel H, Mezes M, Palfy T, Herman A, Gundel J, Lugasi A, Balogh K, Kocsis I, Blazovics A. 2008. Effect of dietary fatty acid pattern on growth, body fat composition and antioxidant parameters in broilers. *Journal of Animal Physiology and Animal Nutrition*, 92: 369-376
- Ferrier IK, Caston LJ, Leeson S, Squires J, Weaver BJ, Holub BJ. 1995. alpha-Linolenic acid-and docosahexaenoic acid-enriched eggs from hens fed flaxseed: influence on blood lipids and platelet phospholipid fatty acids in humans. *The American journal of clinical nutrition*, 62: 81-86
- Fraeye I, Bruneel C, Lemahieu C, Buyse J, Muylaert K, Foubert I. 2012. Dietary enrichment of eggs with omega-3 fatty acids: A review. *Food Research International*, 48: 961-969
- Gakhar N, Goldberg E, Jing M, Gibson R, House J. 2012. Effect of feeding hemp seed and hemp seed oil on laying hen performance and egg yolk fatty acid content: Evidence of their safety and efficacy for laying hen diets. *Poultry Science*, 91: 701-711
- Ghazani SM, Marangoni AG. 2013. Minor components in canola oil and effects of refining on these constituents: A review. *Journal of the American Oil Chemists' Society*, 90: 923-93
- Grobos S, Mendez J, Lazaro R, De Blas C, Mateo G. 2001. Influence of source and percentage of fat added to diet on performance and fatty acid composition of egg yolks of two strains of laying hens. *Poultry Science*, 80: 1171-1179
- Güçlü B, Uyanık F, İşcan K. 2008. Effects of dietary oil sources on egg quality, fatty acid composition of eggs and blood lipids in laying quail. *South African Journal of Animal Science*, 38: 91-100
- Harris WS, Mozaffarian D, Lefevre M, Toner CD, Colombo J, Cunnane SC, Holden JM, Klurfeld DM, Morris MC, Whelan J. 2009. Towards establishing dietary reference intakes for eicosapentaenoic and docosahexaenoic acids. *The Journal of nutrition*, 139: 804-819
- Herber S, Van Elswyk M. 1996. Dietary marine algae promote efficient deposition of n-3 fatty acids for the production of enriched shell eggs. *Poultry Science*, 75: 1501-1507
- House JD, Neufeld J, Leson G. 2010. Evaluating the quality of protein from hemp seed (*Cannabis sativa* L.) products through the use of the protein digestibility-corrected amino acid score method. *Journal of agricultural and food chemistry*, 58: 11801-11807
- Jalali S, Rabiei R, Kheiri F. 2015. Effects of dietary soybean and sunflower oils with and without L-carnitine supplementation on growth performance and blood biochemical parameters of broiler chicks. *Archives Animal Breeding*, 58: 387-394
- Kovalcuks A, Duma M. 2014. Solvent extraction of egg oil from liquid egg yolk. 9th Baltic Conference on Food Science and Technology "Food for Consumer Well-Being", p. 253.
- Lalwani P. 2012. Quail egg nutrition. 2011.
- Laudadio V, Lorusso V, Lastella N, Dhama K, Karthik K, Tiwari R, Alam GM, Tufarelli V. 2015. Enhancement of nutraceutical value of table eggs through poultry feeding strategies. *International Journal of Pharmacology*, 11: 201-212
- Liang J, Appukuttan Aachary A, Thiyam-Holländer U. 2015. Hemp seed oil: Minor components and oil quality. *Lipid Technology*, 27: 231-233
- Milinsk M, Murakami A, Gomes S, Matsushita M, De Souza N. 2003. Fatty acid profile of egg yolk lipids from hens fed diets rich in n-3 fatty acids. *Food chemistry*, 83: 287-292
- Minitab I. 2000. MINITAB statistical software. Minitab Release, 13: 0
- Neijat M, Gakhar N, Neufeld J, House J. 2014. Performance, egg quality, and blood plasma chemistry of laying hens fed hempseed and hempseed oil. *Poultry Science*, 93: 2827-2840
- Nobakht A, Tabatbaei S, Khodaei S. 2011. Effects of different sources and levels of vegetable oils on performance, carcass traits and accumulation of vitamin E in breast meat of broilers. *Curr. Res. J. Biol. Sci*, 3: 601-605
- Reda F, El-Kholy M, Abd El-Hack M, Taha A, Othman S, Allam A, Alagawany M. 2020. Does the use of different oil sources in quail diets impact their productive and reproductive performance, egg quality, and blood constituents? *Poultry Science*, 99: 3511-3518

- Regulation H. 1991. Commission Regulation (EEC) No. 2568/91 of 11 July 1991 on the characteristics of olive oil and olive-residue oil and on the relevant methods of analysis Official Journal L 248, 5 September 1991. Offic. JL, 248: 1-83
- Romanoff AL, Romanoff AJ. 1949. The avian egg. The avian egg.,
- Sapino S, Carlotti ME, Peira E, Gallarate M. 2005. Hemp-seed and olive oils: Their stability against oxidation and use in O/W emulsions. International Journal of Cosmetic Science, 27: 355-355
- Silversides F, Lefrancois M. 2005. The effect of feeding hemp seed meal to laying hens. British Poultry Science, 46: 231-235
- Singh M. 2005. Essential fatty acids, DHA and human brain. The Indian Journal of Pediatrics, 72: 239-242
- Trautwein E. 2001. n-3 Fatty acids—physiological and technical aspects for their use in food. European Journal of Lipid Science and Technology, 103: 45-55
- Tunsaringkarn T, Tungjaroenchai W, Siriwong W. 2013. Nutrient benefits of quail (*Coturnix coturnix japonica*) eggs. International Journal of Scientific and Research Publications, 3: 1-8
- Van Elswyk M, Dawson P, Sams A. 1995. Dietary menhaden oil influences sensory characteristics and headspace volatiles of shell eggs. Journal of food science, 60: 85-89
- Van Elswyk ME. 1997. Comparison of n-3 fatty acid sources in laying hen rations for improvement of whole egg nutritional quality: a review. British journal of Nutrition, 78: S61-S69
- Yalçın H, Ünal MK. 2010. The enrichment of hen eggs with ω -3 fatty acids. Journal of medicinal food, 13: 610-614
- Yin J, Shang X, Li D, Wang F, Guan Y, Wang Z. 2008. Effects of dietary conjugated linoleic acid on the fatty acid profile and cholesterol content of egg yolks from different breeds of layers. Poultry Science, 87: 284-290