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Fat supplementation containing high palmitic acid enriched with lecithin on the performance, egg quality, and fatty acid profile of quail

A. A. Yano[1*], W. Hermana[2], Y. Retnani[2], and I. Syarif[2]
[1]*Vocational School, Universitas Sebelas Maret, Surakarta 57126, Indonesia*
[2]*Department of Animal Nutrition and Feed Science, Faculty of Animal Science, IPB University, Bogor 16680, Indonesia*
**Corresponding e-mail: aan.yano@staff.uns.ac.id*

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ABSTRACT

This study examined the effects of fat supplementation with high palmitic acid enriched with lecithin on the performance, egg quality, and fatty acid profile of quails. This study applied a completely randomized design to 330 female quails (*Cortunix cortunix japonica*) which were allocated into 5 different groups with 3 replicates of 22 birds. The groups were assigned as follows: T0 = commercial diet (control), T1 = commercial diet + 2.5% fat + 6% lecithin of added fat, T2 = commercial diet + 2.5% commercial fat, T3 = commercial diet + 5% fat + 6 % lecithin of added fat, T4 = commercial diet + 5% commercial fat. The results showed that the treatment group did not give effects on performances. However, the treatment group with fat level of 2.5% and 5% increased the score of egg yolk and eggshell thickness. Moreover, the treatment group decreased fat content in terms of saturated fatty acids and n-6/n-3 ratio of quail eggs. In conclusion, fat supplementation containing high palmitic acid enriched with lecithin proves effective in improving egg quality. However, the performance remains relatively similar across the groups.
Keywords: Eggs, Fatty acids, Lecithin, Quail.

INTRODUCTION

Eggs are one of protein sources in human nutrition. Among the egg producers, Japanese quails (*Cortunix cortunix japonica*) are considered as the most affordable egg producer for human consumption. Moreover, a Japanese quail is commonly known for its high egg production (Hrncar *et al.*, 2014; Vali, 2008). The weight of quail egg ranges from 6 to 16 g per egg (Tserveni -Goussi and Fortomaris, 2011). Additionally, the nutrient content of quail eggs is 3 to 4 times higher than that of chicken eggs (Tunsaringkarn *et al.*, 2013). Besides that, some advantages of maintaining quails are low production costs, resistant to disease, fast growth, fast generation intervals, and fast adult sex (Vali, 2008).

Highly productive quails result from an excellent diet and feeding management, in addition to genetic and environmental factors. However, Abu *et al.* (2015) stated that the cost of diet contributes 60% to 80% of the total production cost. The high cost of feed, particularly in developing countries, is primarily attributed to a significant amount of imported feed ingredients (Sugiharto *et al.*, 2018). Using alternative ingredients are highly recommended to reduce the cost. The TCESI (2017) reported that oil palm planting in Indonesia reached 12.037.677 hectares and a great amount of palm oil was highly produced at 7.071.877 tons. In short, each hectare of oil palm equals to four tons of palm oil yearly. Thus, the oil palm waste is a potential feed ingredient due to its abundance such as crude palm oil.

The industry of palm oil is a potential feed source that has not been widely utilized in animal husbandry sector. The palm oil processing produces by-products in the form of fat with high palmitic acid. This fat can be used as a high energy source for quails with low heat increment (Baião and Lara, 2005). Previous studies suggested that fat supplementation can increase egg production and weight (Guclu *et al.*, 2008; Kucukersan *et al.*, 2010). However, previous studies did not reported fat supplementation enriched with lecithin as an emulsifier. Feed containing fat provides a lot of energy; however, fat does not dissolve in water, so emulsifiers are needed to aid in fat digestion (Siyal *et al.*, 2017).

One of emulsifiers that can be used is soy lecithin. Soy lecithin is a by-product of refined soybean oil. Soy lecithin is commercially available containing 65-75% phospholipids, 34% triglycerides, and small number of carbohydrates, pigments, and sterols (Deng, 2021). A study reported that palm oil stabilized by soy lecithin release slowly free fatty acid in vitro gastrointestinal digestion as compared to non-encapsulated control. The inhibitory potential of soy lecithin lipase is probably responsible for this (Sandoval-Cuellar *et al.*, 2020). In addition, soy lecithin was found to effectively enhance the surface elasticity of interfacial films, resulting in the formation of highly stable emulsions (Jiang *et al.*, 2021). A study by Syarif *et al.* (2019) suggested that optimizing quail performance between the ages of 1 to 6 weeks could be achieved by adding 2.5% fat with 6% lecithin. However, given that quails typically start laying eggs at around 6 to 7 weeks of age, as reported by Maeda *et al.* (1997), further investigation is necessary. Therefore, this study examined the effects of fat supplementation with high palmitic acid enriched with lecithin on the performance, egg quality, and fatty acid profile of quails aged 6-12 weeks. We hypothesized that there would be differences in quail performance, egg quality, and fatty acid profile between the control and treatment groups.

MATERIALS AND METHODS

Bird, Housing, and Treatments

This study was conducted in a commercial quail farm in Bogor, West Java, Indonesia. A total of 330 female quails (*Coturnix coturnix japonica*) obtained from Kayumanis Quail Farm, West Java, Indonesia was randomly allocated into 5 groups, each with 3 replicates of 22 birds. The five groups were defined as follows: T0 = commercial diet (control), T1 = commercial diet + 2.5% fat + 6% soy lecithin of added fat, T2 = commercial diet + 2.5% commercial fat, T3 = commercial diet + 5% fat + 6 % soy lecithin of added fat, T4 = commercial diet + 5% commercial fat. All the birds were housed in open cages with natural ventilation, grouped in flocks with cages measuring 50 cm x 60 cm x 40 cm. The temperature ranged from 26.40°C to 29.41°C. The birds were fed 3 times a day in a mash form and given access to water *ad libitum* to prevent stress and improve work efficiency. The lights were turned on from 3:00 PM to 6:00 AM. All the birds were reared up to 48 d starting from 36 d of age.

Production of Fat

The fat used in this study was in the form of triglycerides, which are easier to be absorbed than free fatty acids. Fat with high palmitic acid was a by-product of crude palm oil (CPO) production that was not hydrogenated. It contained more than 85% fat with high palmitic acid and had a high melting point. The process to obtain fat with high palmitic acid in the form of fat granules involved refining crude palm oil (CPO) to produce refined, bleached, and deodorized (RBD) oil. The RBD was then fractionated into solid fractions (Refined Bleached and Deodorized Palm Solid) and liquid fractions (Refined Bleached and Deodorized Palm Liquid). The liquid fraction was then processed into cooking oil for daily use, while the waste from the solid material fraction was then fractionated again into Refined Bleached and Deodorized Soft Solid fraction and Refined Bleached and Deodorized Hard Solid fraction.

Waste from the coarse solid fraction was then processed into fat granules with the help of a flaker and spray cooler to produce the desired shape of the fat granules. High palmitic acid fat is from Indonesia, while fat with commercially high palmitic acid is imported through an Indonesian multi-national company.

Production of Soy Lecithin

The soy lecithin used in this study was from a by-product of the soybean oil biodiesel industry. In the case of local high palmitic acid fat, lecithin was manually mixed into the commercial diet in the same proportion as the commercial fat. Meanwhile, for fat with commercially high palmitic acid, lecithin was incorporated before the formation of high palmitic acid fat granules, utilizing spray cooling technology. Lecithin was mixed in a ratio of 6% with the high palmitic acid fat.

Experimental Diet and Design

The nutrient composition of the diet is detailed in Table 1. The diet consisted of corn, bran, corn gluten, pollard, meat and bone meal, soybean meal, oil, calcium phosphate, calcium carbonate, sodium chloride, amino acids, vitamins, trace minerals, and antioxidants. High palmitic acid fat was manually blended into a mash diet until homogenous. Proximate analysis of commercial diet were done using the AOAC method (1980).

For the high palmitic acid fat samples, the fat levels were analyzed with the AOAC method (2012):989.05, and the fat profiles were determined using gas chromatography (Shimadzu GC-2010, Shimadzu Corporation, Kyoto, Japan) following the AOAC method (2012):969.33. Detailed analysis results are presented in Table 2. Free fatty acids were determined by the AOCS method (Ca 5a-40), water content by the AOCS method (Ca 2b-38), melting point by the AOCS method (Cc 3-25), and iodine numbers by the AOCS method (Cd 1d -92).

Data Collection

The calculation of quail feed consumption involved deducting the leftover diet from the given diet and then dividing it by the number of alive quails. The egg-laying period was determined by multiplying the average hen day production with the average weight of quail eggs. Hen day production (HDP) was computed by dividing the number of egg production by the number of alive quails.

Feed conversion was calculated by dividing the amount of feed consumption by the egg period. The layer phase of feed conversion was specifically calculated when quails began producing more than 15% eggs. Income over feed cost was determined by considering the egg production, feed consumption, and selling price of eggs. Mortality rate was calculated by dividing the number of deceased quails during the maintenance process by the initial number of quails. Egg quality measurements were conducted on a 30% sample of egg production from week 9 to week 12.

The weight of the egg, egg white, egg yolk, and eggshell were obtained through scaling the daily quail egg production. The percentages of

Tabel 1. Nutrient Compositon of Experimental Diets

Variables	Nutrient Content (as fed)
Analyzed chemical composition (%)	
Dry matter	90.80
Ash	15.35
Crude protein	19.13
Crude fat	6.42
Crude fibre	2.57
Gross energy (kcal/kg)	4279.74
Ca	3.6
P total	0.7
Calculated nutrient composition	
ME* (kcal/kg)	3272.08

*Metabolic energy is calculated using a formula by Carre and Rozon (1990).

Table 2. Composition of Fatty Acids and Fat Quality

Fatty Acids	Fat	Commercial Fat
SFA (%w/w)		
$C_{12:0}$ Lauric	0.07	0.11
$C_{14:0}$ Myristic	0.98	1.11
$C_{15:0}$ Pentadecanoic	0.05	0.06
$C_{16:0}$ Palmitic	58.73	61.73
$C_{17:0}$ Heptadecanoic	0.07	0.09
$C_{18:0}$ Stearic	5.06	4.46
$C_{20:0}$ Arachidic	0.27	0.28
$C_{24:0}$ Lignoseric	0.04	0.04
∑ SFA	65.27	67.88
MUFA (%w/w)		
$C_{16:1}$ Palmitoleic	0.06	0.06
$C_{18:1n9}$ Elaidic	0.04	0.03
$C_{18:1n9}$ Oleic	23.64	16.41
∑ MUFA	23.74	16.5
PUFA (%w/w)		
$C_{18:2n6}$ Linoleic	4.84	5.47
$C_{18:3n3}$ Linolenic	0.12	0.38
∑ PUFA	4.96	5.85
∑ Fatty acid (%w/w)	93.97	90.23
∑ n3 (%w/w)	0.12	0.38
∑ n6 (%w/w)	4.84	5.47
PUFA/SFA	0.076	0.086
n-6/n-3	40.33	14.40
Free fatty acid (%)	0.06	0.15
Moisture (%)	0.01	0.03
Slip melting point (°C)	59.20	58.40
Iodine value (g I_2/100g)	14.39	16.50

SFA = saturated fatty acid, MUFA = monounsaturated fatty acid, PUFA = polyunsaturated fatty acid.

the weight of egg white, egg yolk, and eggshell were calculated using their respective formulas. The thickness of the eggshell was measured with a Digital Calipers (Nankai, Japan), averaging measurements at the blunt, middle, and taper tip of the egg.

The score of the egg yolk was determined by comparing it with the standard yolk color on a scale of 1-15 (Ovo yolk color fan, German). Haugh unit value was obtained using a Digital Haugh Tester (Orka, Switzerland), converting the high value of egg white with the provided formula : HU = 100 log (H + 7.57-1.7 W0.37).

The fat levels and egg fatty acid profiles of the egg yolk were analyzed using gas chromatography, involving extraction, methylation, and identification stages. Fat levels were analyzed by the AOAC method (2012):989.05, and fatty acid profiles were obtained using chromatography gas (Shimadzu GC-2010, Shimadzu Corporation, Kyoto, Japan) with the AOAC method (2012):969.33.

Statistical Analysis

The study employed a completely randomized design as the experimental design. Data were tested for normality using the Kolmogorov–Smirnov test. Subsequently, data were analyzed using variance analysis and the Duncan's multiple range test. The fatty acid profile data of the quail egg and the Income Over Feed Cost (IOFC) were analyzed descriptively. A 5% significance level was utilized in the statistical testing. The statistical analysis was conducted using SAS software 9.4.

RESULTS AND DISCUSSION

Quail Performance

It is anticipated that this study will feature absorbable fat within the digestive tract of quails. Thus, this study utilized fat in the form of triglycerides based on the emphasis by Tomkins *et al.* (2010), who highlighted that triglycerides are easier to be absorbed than free fatty acids. The objective was to optimize fat absorption in the quails' bodies. However, the results indicated the supplementation of fat with high palmitic acid enriched with lecithin in control group was not significantly different (P> 0.05) from the treatment groups in feed consumption, feed conversion, egg mass, hen day production (HDP), and mortality (Table 3).

The findings of the current study indicated that the fat added with lecithin was not effective in maximizing the quail performances. The findings align with those of previous research (Isika *et al.*, 2019; Rezaei *et al.*, 2008). Various factors influencing quail performance appear interconnected. Egg production is influenced by diet maintenance management and nutrient content encompassing aspects of quality, quantity, and continuity (Permatahati *et al.*, 2019; Rahmasari *et al.*, 2014; Leeson and Summers, 2005). The fat utilized in this study, which contains a high proportion of palmitic acid, is a derivative of the crude palm oil manufacturing process. It was selected due to its affordability. However, the increase in SFA levels in the feed, which primarily consist of long carbon chains (14-24), appears to hinder nutrient digestion. Consequently, the digestibility of nutrients, decreases with the elevated presence of long-chain fatty acids, particularly SFA with a carbon length of 14-18 (Saraswati *et al.*, 2018). Therefore, the quail performances were relatively similar.

Furthermore, the observed mortality rate in this study remained within a normal range, being lower than 1%. Lukanov *et al.* (2018) reported quail mortality exceeding 1% after 12 weeks. The use of high palmitic acid fat as a supplement demonstrated that quails could maintain normal egg production without causing elevated mortality. Notably, the treatment group, particularly T2, exhibited higher egg production compared to the control group (refer to Figure 1). Corresponding

Table 3. Quail Performances at 36-84 Days of Age

Parameters	Diets					SEM	*p*-value
	T0	T1	T2	T3	T4		
Feed consumption (g/bird/day)	23.64	22.71	22.59	22.61	22.22	0.198	0.223
Egg mass (g/bird/day)	6.590	6.358	6.622	6.175	6.433	0.125	0.843
Hen day production (%)	61.02	58.61	63.10	57.69	59.82	1.201	0.709
Feed conversion	2.919	2.945	2.868	2.975	2.781	0.551	0.872
Mortality (%)	0.000	0.306	0.306	0.102	0.102	0.058	0.392

Table 4. Quail Income Over Feed Cost (IOFC) at 36-84 Days of Age

Description	Diets				
	T0	T1	T2	T3	T4
Feed consumption (kg/quail)	1.159	1.113	1.107	1.108	1.089
Feed cost (Rp/kg)	6550	6676	6861	6803	7173
Feed cost total (Rp/quail) [A]	7589	7431	7596	7538	7810
Egg production (egg/bird)	30	29	31	28	29
Selling price of egg (Rp/egg)	350	350	350	350	350
Total egg sales (Rp/bird) [B]	10465	10051	10822	9894	10259
IOFC (Rp/bird) [B-A]	2877	2620	3227	2356	2449
Difference percentage with T0	0%	-8.91%	12.17%	-18.10%	-14.87%

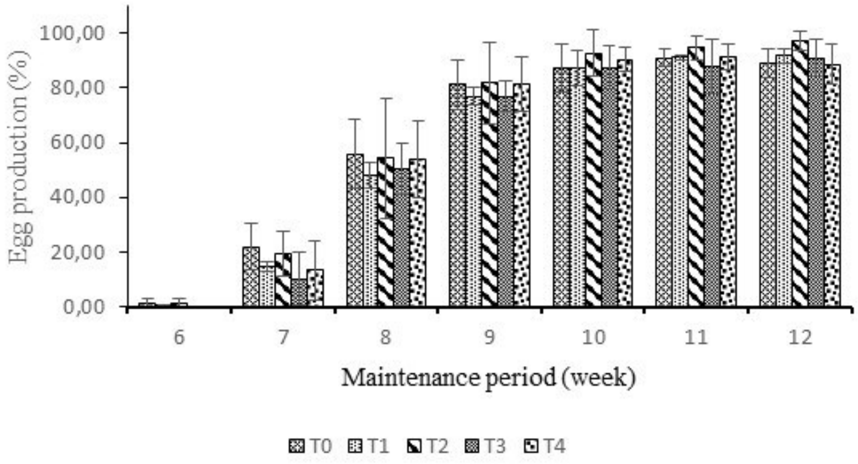

Figure 1. Average value of quail egg production

to the increased egg production, the Income Over Feed Cost (IOFC) indicated that T2 had a higher IOFC than other treatments (Table 4). The IOFC values tended to decrease in accordance with the escalating levels of fat with high palmitic acid supplements enriched with lecithin.

Egg Quality

There was a significant difference ($P < 0.05$) in the thickness of the eggshell and the color score of the egg yolk between the control and treatment groups. Surprisingly, no differences were found ($P > 0.05$) in the weight and percentage of the egg white and yolk, the weight of the eggshell, and the value of the Haugh unit (HU) (Table 5). Olawumi and Ogunlade (2008) stated that the thickness of the eggshell influences the weight of the eggshell. The thickness of the eggshell treated with fat containing high palmitic acid at levels of 2.5% and 5% showed no difference; however, the treatment group exhibited thicker eggshells than the control group. Essentially, the mineral requirements, such as Ca and P, for laying quails in this study have been fulfilled as indicated in Table 1. Several studies have highlighted the optimal Ca and P levels necessary for improving egg production in Japanese quails, ranging from 2.50% to 3.16% for Ca and 0,33% to 0.38% for P (Stanquevis *et al.*, 2021; Rostagno *et al.*, 2017; Costa *et al.*, 2010).

Given the relatively high Ca level (3.6%) observed in this study, a remarkable fact is emerging that defies belief but somehow makes perfect sense. Nobakht *et al.* (2010) emphasized that the inclusion of lipid supplements in poultry diets may interfere with mineral metabolism. Diets rich in Ca (ranging from 3.6% to 4.0%) could exacerbate the formation of insoluble calcium-fatty acid complexes (Leeson and Summers, 1997), affecting its bioavailability for processes like eggshell formation (Josling *et al.*, 2019). In conjunction with previous studies, a more captivating observation was noted. Atteh and Leeson (1983) reported that a significant proportion, specifically 62.6% and 70.6%, of the total fat excreted by poultry existed in the form of SFA soaps, particularly palmitic acid. It appears that a high palmitic acid content in the diet does not effectively contribute to the thickening of quail eggshells. Correspondingly, Hunton (2005) noted that eggshell quality characteristics showed no significant response to variations in dietary fatty acids.

It is believed that compensatory effects may occur when there is a lack of calcium in the diet. Orban and Roland (1990) suggested that poultry naturally utilize skeletal calcium reserves to compensate for deficiencies in dietary or intestinal calcium during formation. This compensatory mechanism may shed light on the limited responsiveness of eggshell quality traits to alterations in dietary fatty acid profile and saturation. Additionally, Atteh and Leeson (1985) found that dietary fatty acid supplementation at 8% had minimal to no adverse impact on the mineral metabolism related to eggshell formation.

Table 5. Quail Egg Quality at 64-84 Days of Age

Parameter	Diets					SEM	*p*-value
	T0	T1	T2	T3	T4		
Egg weight (g/egg)	11.26	11.37	11.14	11.30	11.44	0.044	0.241
Egg albumen							
Weight (g/egg)	5.063	4.958	5.105	5.216	5.292	0.050	0.242
Percentage (%)	44.93	43.61	45.82	46.20	46.24	0.388	0.139
Egg yolk							
Weight (g/egg)	4.491	4.622	4.280	4.294	4.351	0.048	0.087
Percentage (%)	39.89	40.66	38.41	37.95	38.03	0.434	0.164
Yolk color score	3.933^{b}	4.868^{a}	4.997^{a}	4.848^{a}	4.750^{a}	0.119	0.006
Egg shell							
Weight (g/egg)	1.709	1.789	1.757	1.791	1.800	0.023	0.768
Percentage (%)	15.19	15.74	15.77	15.84	15.74	0.177	0.823
Thickness (mm)	0.158^{d}	0.165^{cd}	0.179^{ab}	0.171^{bc}	0.181^{a}	0.003	0.001
Haugh unit	89.81	88.85	88.96	90.54	89.45	0.284	0.347

Lowercase superscript letters in the same row indicate significant differences (P<0.01).

Apart from the unexpected findings, forming strong quail eggshell is important. Narinc *et al.* (2015) added that the quality of eggshells is crucial for protecting eggs against chemical and microbial influences. Moreover, eggshells also regulate the exchange of water and gas through the pores of the eggs. Therefore, the quality of eggshells is not only important for economic reasons but also for the safety of human health. In addition, Ketta and Tumova (2016) stated that eggshells must be strong enough to prevent failure during egg packaging and transport.

Despite the similar results between the control and treatment groups, the total egg weight, weight of the egg yolk, weight of the egg white, and eggshell in this study (Table 5) are higher than the results reported by Bagh *et al.* (2016), which were 10.58 ± 0.30 g, 3.42 ± 0.08 g, 4.78 ± 0.19 g, 1.42 ± 0.02 g, respectively. In alignment with the egg weight, the egg percentages in terms of egg white, egg yolk, and eggshell (Table 5) are higher than those reported in previous studies by Lalliankimi (2017), Hilmi *et al.* (2015), and Lalliankimi (2017). Egg weight, in general, is influenced by genetics, age, body weight, environmental conditions, and feed nutrient content (Zita *et al.*, 2013; Zita *et al.*, 2009; Campbell *et al.*, 2009). Fat is one of the nutrient components, the results emphasize that fat containing palmitic acid enriched with lecithin is not able to significantly improve egg weight and percentage. However, the inclusion of fat in poultry diet is vital to meet energy requirements and achieve excellent animal performance (Tenório *et al.*, 2021).

The values of HU (Table 5) were slightly higher than those reported in a previous study by Stojčić *et al.* (2012), which had a range of 83.65-86.1. Zhang *et al.* (2023) suggested that HU declines with aging, raising the suspicion that the previous study involved older birds than the current one. However, it remains unclear as the bird age in the previous study is not explicitly stated. Additionally, the findings of this study are categorized as AA quality based on the values of HU according to the USDA (2011) classification. USDA (2011) stipulates that eggs with AA quality will have an HU value higher than 72, while A quality is 60-72, B quality is 31-60, and C quality is less than 31.

Unlike other performance parameters, the color of the yolk is closely related to consumer preferences for eggs. Eggs in the treatment group scored higher for egg yolk color than those in the control group. The current findings are in line with the study of Mandalawi *et al.* (2015), indicating that the addition of lecithin is able to improve the color of egg yolks with a 4% concentration. In this study, the lecithin content is 2% higher compared to the previous study, suggesting a probable significant enhancement in egg yolk color. The high concentration of lecithin in the diet has been associated with improved fat digestion, thus facilitating the absorption of the xanthophyll responsible for the vibrant hue of egg yolk (Baião and Lara, 2005). The coloring substances in lecithin include carotenoids, chlorophyll substances, and chocolate substances (Lezerovich, 1985).

Fatty Acid Profile

The fat levels of egg in the treatment groups were lower than those in the control group (Table 6). The results are surprising given the absence of fat supplementation in the control group. Unfortunately, to our best knowledge, no single studies reported a similar findings. On the contrary, however, Göçmen *et al.* (2021) observed a notable increase in the fatty acid composition of quail eggs when supplemented with plant-based oil rich in linoleic acids, ranging from 55 to 60%. However, the present study indicates a linoleic acid content of only 4-5%. This unexpected result might be linked to the high presence of palmitic acid in the diet and the low level of linoleic acid. A study suggests that when the dietary linoleic acid level is low, increasing palmitic acid levels can lead to increase in cholesterol in the plasma (French *et al.*, 2002). Hence, it is plausible that the fat is primarily converted into cholesterol in the plasma before being absorbed into the egg.

The unremarkable results regarding the fat content in the eggs appear surprisingly advantageous. Hu *et al.* (2001) suggested that

Table 6. Quail Egg Fatty Acid Profile at 78-84 Days of Age

Fatty acid	Diets				
	T0	T1	T2	T3	T4
SFA (%w/w)					
$C_{14:0}$ Myristic	0.37	0.35	0.35	0.41	0.47
$C_{15:0}$ Pentadecanoic	0.04	0.04	0.04	0.06	0.06
$C_{16:0}$ Palmitic	24.25	20.93	20.63	24.04	25.51
$C_{17:0}$ Heptadecanoic	0.08	0.07	0.08	0.10	0.11
$C_{18:0}$ Stearic	8.04	6.93	7.12	8.15	8.48
$C_{20:0}$ Arachidic	0.02	1.33	0.02	0.02	0.03
$C_{22:0}$ Bahuric	0.03	0.02	0.02	0.02	0.02
∑ SFA	32.83	29.67	28.26	32.80	34.68
MUFA (%w/w)					
$C_{14:1}$ Myristoleic	0.07	0.06	0.05	0.07	0.09
$C_{16:1}$ Palmitoleic	3.83	3.33	2.92	3.41	4.00
$C_{17:1}$ Heptadecanoic-Cis-10	0.10	0.09	0.09	0.10	0.12
$C_{18:1n9t}$ Elaidic	0.18	0.15	0.15	0.15	0.18
$C_{18:1n9c}$ Oleic	44.42	35.79	35.64	38.67	41.37
$C_{20:1}$ Eicosanoic-Cis-11	0.11	0.08	0.08	0.08	0.12
∑ MUFA	48.71	39.5	38.93	42.48	45.88
PUFA (%w/w)					
$C_{18:2n6c}$ Linoleic	10.43	9.26	8.96	10.05	10.81
$C_{18:3n3}$ Linolenic	0.16	0.15	0.15	0.16	0.21
$C_{18:3n6}$ Linolenic-y	0.17	0.17	0.15	0.19	0.19
$C_{20:2}$ Eicosapenoic-14-Cis-11	0.07	0.07	0.07	0.07	0.06
$C_{20:3n6}$ Ericosatrienoic-14-Cis-8,11	0.11	0.08	0.09	0.09	0.11
$C_{20:4n6}$ Arachidonic	1.46	1.33	1.36	1.53	1.68
$C_{22:6n3}$ Docosahexanoic-19-Cis-4,7	0.22	0.24	0.23	0.25	0.27
∑ PUFA	12.62	11.3	11.01	12.34	13.33
∑ Fatty acid (%w/w)	94.16	80.47	78.2	87.62	93.89
∑ omega 3 (n3) (%w/w)	0.38	0.39	0.38	0.41	0.48
∑ omega 6 (n6) (%w/w)	12.17	10.84	10.56	11.86	12.79
PUFA/SFA	0.384	0.381	0.390	0.376	0.384
n-6/n-3	32.03	27.80	27.79	28.93	26.65
Fat (%w/w)	28.78	27.04	28.36	27.10	27.72

SFA = saturated fatty acid, MUFA = monounsaturated fatty acid, PUFA = polyunsaturated fatty acid.

reducing the total fat content in food is better to prevent the risk of heart disease. The addition of lecithin to fat could aid in the more complete absorption of fat. The differences in the composition of egg fatty acids were likely caused by variations in the proportions of saturated fatty acids and unsaturated fatty acids in the two sources of fat, influencing the digestibility and absorption of nutrients.

The supplementation of fat with high palmitic acid also increased the Docosahexaenoic Acid (DHA) content in quail eggs. Grobas *et al.* (1999) explained that the increase in egg DHA is attributed to an elevation of α-linolenic acid in the food. This supplementation of fat with high palmitic acid could enhance the omega-3 content in quail eggs, which are generally not rich in omega-3. Rymer *et al.* (2010) further emphasized that omega-3 is beneficial to prevent cardiovascular disease. Additionally, the supplementation of fat enriched with lecithin led to a reduction in saturated fatty acids in eggs. Gecgel *et al.* (2015) have reported that saturated fatty acids in eggs can have negative effects on human health, such as cardiovascular disease, coronary heart disease, and insulin resistance.

The increased level is observed not only in DHA levels but also in the PUFA/SFA ratio. The supplementation of fat with high palmitic acid also tends to increase the PUFA/SFA ratio, approaching that of the control treatment. Villaverde *et al.* (2005) emphasized that an increased PUFA/SFA ratio can have health benefits for humans. Furthermore, the supplementation of fat with high palmitic acid has the potential to reduce the n-6/n-3 ratio in quail eggs. Mandal *et al.* (2014) suggested that a lower n-6/n-3 ratio could lead to higher levels of EPA and DHA, which are beneficial for human health. Ulbricht *et al.* (1991) also mentioned that a lower n-6/n-3 ratio reduces the atherogenic index and thrombogenic index, thereby reducing the risk of arteriosclerosis and thrombosis. Additionally, the supplementation of fat with high palmitic acid reduces total monounsaturated fatty acids in eggs. Consistently, Cherian and Quezada (2016) indicated that adding fat can reduce monounsaturated fatty acids (MUFA). Thiebaut *et al.* (2007) suggested that a high consumption of MUFA may increase the risk of prostate cancer, while Jackson *et al.* (2012) indicated that high MUFA consumption may increase the risk of breast cancer.

CONCLUSION

Our findings underscore the importance of fat supplementation enriched with lecithin in the quail diet. These results have significant implications for fat digestion, suggesting avenues for further research and potential application in the quail farming industry. Moving forward, it is essential to analyze lipase enzymes in supplemented fats, especially in the laying phase, as the addition of lecithin may not be sufficient to aid in the proper digestion and absorption of fat. Manual lecithin mixing should be avoided; instead, it is preferable to use spray cooling technology before the fat solidifies into granules.

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