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Effect of Dietary Linseed on Egg Quality of Laying Quail

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Abstract: This experiment was performed to investigate the effect of dietary supplementation with linseed on egg quality of laying quail. A total of 320 Japanese quail (*Coturnix coturnix japonica*) 9-wk old were allocated to 4 treatment groups with 4 replicates containing 20 quail each. Birds were fed commercial diet containing 0% (C), 2% (T1), 4% (T2) or 6% (T3) linseed. Birds received water and diet *ad libitum* during the total period of experiment. Egg quality characteristics were monitored over 3 consecutive 21-d periods. Egg quality criteria involved in this experiment were egg weight, yolk diameter, yolk height, yolk weight, albumen height, albumen weight, shell weight, shell thickness, Haugh unit, albumen percentage, yolk percentage and shell percentage. Results revealed that supplementing diet of laying quail with linseed resulted in significant increase in total means of egg weight, yolk diameter, albumen height, shell thickness, Haugh unit, albumen percentage and albumen weight. Total means of shell weight and yolk percentage were not significantly ($p>0.05$) different from quails consuming 0, 2, 4 or 6% linseed; However, total mean of shell percentage was reduced ($p<0.05$) in laying quails fed linseed when compared to control group. In conclusion, Feeding laying quails with different levels of linseed (2%, 4%, or 6%) caused significant improvement as regards most of egg quality parameters included in this experiment. Therefore, adding linseed to the ration could be used as a good tool for improving productive performance of Japanese quail.

Key words: Linseed, egg quality, laying quail

INTRODUCTION

The egg is considered a functional food, as it is a source of protein, vitamins and lipids, such as phospholipids and polyunsaturated fatty acids (Meluzzi *et al*., 2000; Anton *et al*., 2006). In the production of eggs rich in n-3 fatty acids, there is increasing interest in maximizing the use of feed stuffs containing these nutrients because there is a correlation between their levels in feeds and in the yolk (Leeson *et al*., 1998).

The egg is naturally poor in linolenic acid and dose not contains Eicosapentoenoic (EPA) and docosahexaenoic (DHA) fatty acids.

Omega-3 polyunsaturated fatty acids have been extensively studied in human health, as well as n-6 fatty acids, which are considered essential in human diets. Linolenic acid (LNA, 18 : 3, n-3) can be metabolically converted into eicosapentoenoic (EPA, 20 : 5, n-3) and docosahexaenoic (DHA, 22 : 6, n-3) fatty acids, but the enzymes involved in this process are common to the elongation and desaturation of LNA and therefore the competition with n-6 fatty acids reduces the amount of converted LNA (Baucells *et al*., 2000).

One of the main dietary sources of long-chain n-3 Polyunsaturated Fatty Acids (PUFA) is fish, which is rich in EPA and DHA. Certain seeds, particularly linseed, are rich in LNA, a precursor of those fatty acids (EPA and DHA) (Calder, 1998). The enrichment of layer feeds with marine-fish oils, algae and oilseeds, such as linseed, promote the rapid incorporation of omega-3 fatty acids into the egg yolk (VanElswyk, 1997). In addition to its high content in LNA (50-55%), the interest in linseed use is related to the presence of dietary fiber, lignans and phenolic compound which may reduce risk factors for cardiovascular diseases and cancer (Chen *et al*., 1994). Taking these aspects into consideration, the objective of this experiment was to evaluate the effect of feeding linseed on egg quality parameters of laying quail.

MATERIALS AND METHODS

Birds and treatments: This study was carried out at the Poultry Research Station, State Board of Agricultural Research, Ministry of Agriculture to study the effect of feeding diets containing different levels of linseed on egg quality traits of laying quails. A total number of 320 Japanese quail (*Coturnix coturnix japonica*) hens, with 9 weeks of age at the beginning of the trial, was distributed in a completely randomized experimental design into 4 treatments, with 4 replicates of 20 birds each (80 birds per each treatment). The experimental diets were: A control diet (C) was containing no linseed; T1 was containing 2% linseed; T2 was containing 4% linseed and T3 was containing 6% linseed. The experimental diets were formulated to be isoenergetic (2900 ME/kg of diet) and isonitrogenous (20% crude protein) and to supply birds' requirements according to NRC (1994). The ingredient and chemical composition

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Table 1: Ingredient and calculated composition of the diet fed to quail hens

Ingredients (%)	C	T1	T2	T3
Yellow corn	56.10	55.40	54.75	54.00
Soybean meal (44%)	31.10	30.20	29.20	28.40
Protein concentrate(1)	5.00	5.00	5.00	5.00
Vegetable oil	2.00	1.60	1.25	0.80
Linseed(2)	0.00	2.00	4.00	6.00
Limestone	4.90	4.90	4.90	4.90
Dicalcium phosphate	0.60	0.60	0.60	0.60
Salt	0.30	0.30	0.30	0.30
Calculated content(3)				
ME (kcal/kg)	2903.00	2902.00	2905.00	2900.00
Crude protein (%)	20.00	20.00	20.00	20.00
Lysine (%)	1.10	1.10	1.10	1.10
Methionine + Cystine (%)	0.77	0.77	0.77	0.77
Calcium (%)	2.55	2.55	2.55	2.55
Available phosphorus (%)	0.33	0.33	0.33	0.33
Linoleic acid (C 18:3n 6) (%)	1.53	1.58	1.65	1.70
Linolenic acid (C 18:3n 3) (%)	-	0.34	0.67	1.01
Linoleic/Linolenic acid ratio	153.00	4.65	2.46	1.68

[1]Protein concentrate provided per kg: 30% crude protein; 2000 ME/kg; 1.85 lysine; 2.3% methionine; 2.8% methionine + cystine; 4% calcium; 2.5% available phosphorus; 2.3% sodium; 6.5% crude fiber ; 4% crude fat and other nutrients (vitamins + minerals) meet with NRC (1994) specification.

[2]Linseed contain 24% crude protein; 3960 ME/kg; 0.89 lysine; 0.44 methionine; 0.87 methionine + cystine; 0.28 calcium; 0.55 available phosphorus; 2.3% sodium; 6.3% crude fiber; 35.9% crude fat; 5.39% Linoleic acid; 16.8% Linolenic acid (Ensminger *et al*., 1990; Vaisey -Genser, 1994).

[3]Calculated composition was according to NRC (1994)

of the experiment diets are presented in Table 1. Birds received water and feed *ad libitum* during the entire experimental period. Hens were maintained on 16 h: 8 h light: darkness photoperiod.

Egg quality traits: Egg quality criteria (egg weight, yolk diameter, yolk height, yolk weight, albumen height, albumen weight, shell weight, shell thickness, Haugh unit, albumen percentage, yolk percentage and shell percentage) were measured at 3rd week, 6th week and 9th week of the trial, using 30 eggs from each experimental unit. These parameters of egg quality were determined according to Guclu *et al*. (2008).

Statistical analysis: The data were analyzed statistically using the General Linear Models procedure of SAS (2000). Significant differences between treatment means were separated using the Duncan's multiple range test with 5% and 1% probability (Duncan, 1955).

RESULTS

Total means of egg weight and yolk diameter (Table 2 and 3) showed a significant effect ($p<0.01$) of feeding linseed, with treated hens produced the heaviest eggs and highest yolk diameter when compared to control hens.

Dietary linseed at levels of 2% (T1) and 4% (T2) did not differ significantly from control group as regards total means of yolk height, although there was clear trend for this trait to be higher in T1 and T2 as compared with control group (Table 4). However, T3 group surpasses C group with relation to this trait, while there were no significant differences among T1, T2 and T3 groups.

The effect of inclusion linseed into the quail diet on yolk weight is presented in Table 5. The date obtained showed that total means of yolk weight of quail groups received diet supplemented with linseed at levels of 4% (T2) and 6% (T3) were higher ($p<0.01$) with relation to C group, but there were no significant differences between T1, T2 and T3 groups and between C and TI groups, although there was a trend for this characteristic to be higher in T1 group in comparison with C group.

Adding linseed to the quail diets resulted in highly significant ($p<0.01$) increase concerning albumen height and albumen weight when compared to C group (Table 6 and 7).

Shell weight of the quail eggs was not affected by supplementing the diet with linseed (Table 8), while total means of shell thickness were significantly ($p<0.01$) higher in treated groups (T1, T2 and T3) as compared with C group (Table 9).

Results of this experiment revealed that laying quails fed the ration supplemented with linseed (T1, T2 and T3) excel C group in respect to total means of Haugh unit and albumen weight expressed as a percentage of egg weight (Tables 10 and 11).

Total means of yolk weight expressed as a percentage of egg weight were not different ($p>0.05$) between experimental groups, in spite of there was a trend for this trait to be higher in C group as compared with treatment groups (Table 12), whereas C group recorded the highest ($p<0.01$) total mean of shell weight expressed as a percentage of egg weight in comparison with treatment groups (T1, T2 and T3) (Table 13).

Table 2: Effect of dietary supplementation with linseed on egg weight (g) (Mean±SE) of laying quail

Weeks of experiment	Treatments C	T1	T2	T3	Level of significance
3	11.04±0.19[b]	11.17±0.34[a]	12.27±0.23[a]	11.96±0.14[a]	**
6	9.40±0.20[c]	10.40±0.16[b]	11.30±0.16[a]	10.86±0.11[a]	**
9	10.86±0.23[b]	11.71±0.20[a]	11.80±0.14[a]	11.13±0.16[a]	**
Total means	10.44±0.13[c]	11.09±0.16[b]	11.79±0.09[a]	11.32±0.09[a]	**

C: Control without linseed; T1: Supplemented with 2% linseed; T2: Supplemented with 4% linseed; T3: Supplemented with 6% linseed. [a,b,c]Means with a row lacking a common superscript differ significantly. **p<0.01

Table 3: Effect of dietary supplementation with linseed on yolk diameter (mm) (Mean±SE) of laying quail

Weeks of experiment	Treatments C	T1	T2	T3	Level of significance
3	23.36±0.12[c]	23.88±0.18[b]	24.22±0.15[b]	24.78±0.14[a]	**
6	23.74±0.22[b]	24.63±0.23[a]	24.50±0.16[a]	24.89±0.21[a]	**
9	24.05±0.12[c]	24.73±0.21[b]	25.04±0.19[b]	25.82±0.22[a]	**
Total means	23.7±0.05[c]	24.41±0.09[b]	24.58±0.02[b]	25.16±0.08[a]	**

C: Control without linseed; T1: Supplemented with 2% linseed; T2: Supplemented with 4% linseed; T3: Supplemented with 6% linseed. [a,b,c]Means with a row lacking a common superscript differ significantly. **p<0.01

Table 4: Effect of dietary supplementation with linseed on yolk height (mm) (Mean±SE) of laying quail

Weeks of experiment	Treatments C	T1	T2	T3	Level of significance
3	10.21±0.23[c]	10.55±0.15[b]	11.00±0.12[ab]	11.38±0.17[a]	**
6	10.39±0.29[b]	10.82±0.16[a]	10.40±0.15[b]	10.65±0.2[a]	*
9	10.34±0.31[b]	10.71±0.12[a]	10.66±0.13[ab]	10.86±0.13[a]	*
Total means	10.31±0.19[b]	10.70±0.09[ab]	10.69±0.08[ab]	10.96±0.13[a]	**

C: Control without linseed; T1: Supplemented with 2% linseed; T2: Supplemented with 4% linseed; T3: Supplemented with 6% linseed. [a,b,c]Means with a row lacking a common superscript differ significantly. **p<0.01; *p<0.05

Table 5: Effect of dietary supplementation with linseed on yolk weight (g) (Mean±SE) of laying quail

Weeks of experiment	Treatments C	T1	T2	T3	Level of significance
3	3.60±0.078[c]	3.53±0.076[c]	4.30±0.097[a]	3.86±0.11[b]	**
6	3.53±0.095[c]	3.83±0.069[a]	3.66±0.137[b]	3.76±0.11[a]	*
9	3.73±0.068[b]	3.90±0.085[a]	3.81±0.078[a]	3.78±0.087[ab]	*
Total means	3.62±0.055[b]	3.75±0.056[ab]	3.92±0.071[a]	3.80±0.056[a]	**

C: Control without linseed; T1: Supplemented with 2% linseed; T2: Supplemented with 4% linseed; T3: Supplemented with 6% linseed. [a,b,c]Means with a row lacking a common superscript differ significantly. **p<0.01; *p<0.05

Table 6: Effect of dietary supplementation with linseed on albumen height (mm) (Mean±SE) of laying quail

Weeks of experiment	Treatments C	T1	T2	T3	Level of significance
3	3.57±0.14[b]	3.70±0.13[b]	3.78±0.12[b]	4.18±0.13[a]	**
6	3.75±0.12[b]	4.19±0.11[a]	3.73±0.08[b]	4.07±0.15[a]	**
9	3.19±0.18[b]	3.81±0.17[a]	3.86±0.10[a]	3.75±0.04[a]	**
Total means	3.50±0.07[c]	3.90±0.03[b]	3.79±0.04[b]	4.00±0.08[a]	**

C: Control without linseed; T1: Supplemented with 2% linseed; T2: Supplemented with 4% linseed; T3: Supplemented with 6% linseed. [a,b,c]Means with a row lacking a common superscript differ significantly. **p<0.01

Table 7: Effect of dietary supplementation with linseed on albumen weight (g) (Mean±SE) of laying quail

Weeks of experiment	Treatments C	T1	T2	T3	Level of significance
3	6.34±0.13[b]	6.80±0.36[a]	7.10±0.17[a]	7.22±0.09[a]	**
6	5.14±0.17[d]	5.68±0.13[c]	6.76±0.13[a]	6.19±0.10[b]	**
9	6.17±0.18[b]	6.88±0.17[a]	7.02±0.14[a]	6.39±0.12[a]	**
Total means	5.71±0.20[c]	6.45±0.16[b]	6.96±0.08[a]	6.60±0.07[ab]	**

C: Control without linseed; T1: Supplemented with 2% linseed; T2: Supplemented with 4% linseed; T3: Supplemented with 6% linseed. [a,b,c]Means with a row lacking a common superscript differ significantly. **p<0.01

Table 8: Effect of dietary supplementation with linseed on shell weight (g) (Mean±SE) of laying quail

Weeks of experiment	Treatments				Level of significance
	C	T1	T2	T3	
3	1.62±0.496[a]	0.84±0.03[b]	0.87±0.022[b]	0.87±0.21[b]	*
6	0.73±0.028	0.89±0.027	0.88±0.028	0.91±0.027	NS
9	0.97±0.017	0.94±0.026	0.97±0.062	0.96±0.020	NS
Total means	1.10±0.017	0.89±0.016	0.91±0.019	0.91±0.016	NS

C: Control without linseed; T1: Supplemented with 2% linseed; T2: Supplemented with 4% linseed; T3: Supplemented with 6% linseed. [a,b,c]Means with a row lacking a common superscript differ significantly. *p<0.05; NS = not significant (p>0.05)

Table 9: Effect of dietary supplementation with linseed on shell thickness (mm) (Mean±SE) of laying quail

Weeks of experiment	Treatments				Level of significance
	C	T1	T2	T3	
3	0.196±0.0079[c]	0.220±0.0091[b]	0.256±0.0062[a]	0.245±0.0081[a]	**
6	0.208±0.0077[a]	0.207±0.0062[a]	0.186±0.0061[b]	0.189±0.0054[ab]	*
9	0.211±0.0038[b]	0.217±0.0077[b]	0.229±0.0072[ab]	0.238±0.0074[a]	*
Total means	0.205±0.0036[b]	0.214±0.0057[a]	0.223±0.0037[a]	0.224±0.0039[a]	**

C: Control without linseed; T1: Supplemented with 2% linseed; T2: Supplemented with 4% linseed; T3: Supplemented with 6% linseed. [a,b,c]Means with a row lacking a common superscript differ significantly. **p<0.01; *p<0.05

Table 10: Effect of dietary supplementation with linseed on haugh unit (Mean±SE) of laying quail

Weeks of experiment	Treatments				Level of significance
	C	T1	T2	T3	
3	84.42±0.85[b]	85.15±0.80[a]	84.70±0.82[b]	87.38±0.73[a]	*
6	87.02±0.70[ab]	88.64±0.72[a]	85.27±0.48[b]	87.56±0.84[a]	**
9	81.97±1.35[b]	85.24±1.13[a]	85.65±0.64[a]	85.56±0.26[a]	*
Total means	84.47±0.45[b]	86.34±0.27[a]	85.21±0.24[a]	86.83±0.44[a]	**

C: Control without linseed; T1: Supplemented with 2% linseed; T2: Supplemented with 4% linseed; T3: Supplemented with 6% linseed. [a,b,c]Means with a row lacking a common superscript differ significantly. **p<0.01; *p<0.05

Table 11: Effect of dietary supplementation with linseed on albumen percentage (%) (Mean±SE) of laying quail

Weeks of experiment	Treatments				Level of significance
	C	T1	T2	T3	
3	57.37±0.68[b]	60.29±1.58[a]	57.78±0.52[ab]	60.40±0.32[a]	*
6	54.63±0.97[b]	54.56±0.65[b]	59.89±1.12[a]	57.07±0.98[a]	**
9	56.64±0.53[b]	58.65±0.73[a]	59.43±0.81[a]	57.42±0.62[a]	**
Total means	54.70±1.74[b]	58.07±0.73[a]	59.02±0.50[a]	58.34±0.35[a]	**

C: Control without linseed; T1: Supplemented with 2% linseed; T2: Supplemented with 4% linseed; T3: Supplemented with 6% linseed. [a,b,c]Means with a row lacking a common superscript differ significantly. **p<0.01; *p<0.05

Table 12: Effect of dietary supplementation with linseed on yolk percentage (%) (Mean±SE) of laying quail

Weeks of experiment	Treatments				Level of significance
	C	T1	T2	T3	
3	32.55±0.34[b]	32.06±1.21[b]	35.05±0.53[a]	32.28±0.31[b]	**
6	37.63±0.89[a]	36.92±0.72[ab]	32.35±1.07[c]	34.58±0.39[bc]	**
9	34.44±0.52[a]	33.32±0.65[ab]	32.33±0.62[b]	33.98±0.64[ab]	*
Total means	34.68±0.33	33.92±0.65	33.28±0.51	33.59±0.40	NS

C: Control without linseed; T1: Supplemented with 2% linseed; T2: Supplemented with 4% linseed; T3: Supplemented with 6% linseed. [a,b,c]Means with a row lacking a common superscript differ significantly. **p<0.01; *p<0.05; NS = not significant (p>0.05)

Table 13: Effect of dietary supplementation with linseed on shell percentage (%) (Mean±SE) of laying quail

Weeks of experiment	Treatments				Level of significance
	C	T1	T2	T3	
3	10.08±0.59[a]	7.66±0.47[b]	7.16±0.25[b]	7.32±0.20[b]	**
6	7.74±0.26[b]	8.53±0.21[a]	7.76±0.19[b]	8.36±0.22[a]	**
9	8.92±0.14[a]	8.02±0.22[b]	8.24±0.54[b]	8.60±0.13[b]	**
Total means	8.96±0.20[a]	8.02±0.14[b]	7.70±0.18[b]	8.07±0.12	**

C: Control without linseed; T1: Supplemented with 2% linseed; T2: Supplemented with 4% linseed; T3: Supplemented with 6% linseed. [a,b,c]Means with a row lacking a common superscript differ significantly. **p<0.01

DISCUSSION

Trials conducted in the past have focused on how linseed-based diets affect egg quality parameters using chicken (Novak and Sceideler, 2001; Bean and Leeson, 2003; Basmacoglu *et al*., 2003). However, there have been no reports regarding the egg quality traits using a laying quail fed linseed. The positive results obtained in the current experiment when laying quail fed the diets supplemented with linseed regarding egg weight, yolk diameter, yolk height, albumen height, yolk weight, shell thickness and Haugh unit may be attributed to hormones metabolism regulation by dietary phytoestrogens, mainly estrogen (Caston *et al*., 1994; Aydin *et al*., 2006). Souza *et al*. (2008) reported that linseed contain high quantity of phytoestrogens like lignans and isoflavones which play important role in regulate reproductive performance, egg quality and fatty acid profile of eggs of semi-heavy layers. The lignans are a group of chemical compounds found in plants, particularly in linseed. Lignans are one of the major classes of phytoestrogens, which are estrogen-like chemicals and also act as antioxidants. Lignans function as phytoestrogens, which are substances widely distributed in plants that are similar in structure to estrogens. Due to the similarities, the phytoestrogens from linseed (enterolactone and enterodiol) may impact estrogen metabolism for the better. They do this by binding to estrogen receptors on cell membranes and either block the action of the stronger steroidal estrogens or act like weak estrogens when the body is deficient. This can alter one's exposure to estrogen and therefore influence such things as hormone-sensitive cancers and osteoporosis (Dawson, 2008). Lignans are being recognized as one of the most beneficial phytoestrogen foods substances, particularly in regards to hormone-sensitive cancer prevention. It is believed that lignans protect against cancers by inhibiting certain enzymes involved in hormone metabolism, reducing the availability of estrogen and interfering with tumor cell growth (Tou *et al*., 1998). Ward *et al*. (2001) reported that there was a positive association between high levels of lignans in the body with reduced risks of prostate cancer, ovarian cancer, breast cancer, osteoporosis and cardiovascular diseases. Begum *et al*. (2004) summarized the benefits of lignan for many cases as follows: Energy levels, sleep patterns, immune support, hormone health, constipation, digestion, anti-fungal, anti-viral, anti-parasitical, skin conditions, hair and anti-carcinogenic. A rich source of minerals, omega 3-fatty acids, phytoestrogens and soluble and insoluble fiber, gave abundant evidence that supports the value of linseed in preventing diverse illnesses such as heart disease and cancer as well as helping to address common ailments such as digestive irregularity and enhancing reproductive performance in both males and females (Dawson, 2008). Guilliams (2000) reported that six times richer than most fish oils in n-3, linseed (*Linum usitatissimum*) and its oil are perhaps the most widely available botanical source of n-3. Linseed oil consists of approximately 55% Alpha Linolenic Acid (ALA). Linseed like chia contains approximately three times as much n-3 as n-6. However, 15 grams of linseed provides ca. 8 grams of ALA, which converted in the body to EPA and DHA. Dahl *et al*. (2005) indicated that linseed is a rich source of both soluble and insoluble fiber. Soluble fiber forms a gel-like matrix with water that adds bulk to stools and promotes more regular bowel movements. Nutritional scientists believe that insoluble fiber found in linseed helps slow the sugar into the blood stream following a meal, preventing spikes in blood glucose levels (Dawson, 2008). For many years, it has been known that polyunsaturated fatty acids play a role in reducing the risk of heart disease. Current research findings suggest that the omega-3 fatty acids help lower blood triglycerides and cholesterol levels. Omega-3 fatty acids are also required for normal growth and development, good production and distinguished reproductive performance (Leskanich and Noble, 1997). Pruthi *et al*. (2007) indicated that in the case it was the chicken, omega-3 enriched eggs are produced by altering the diet of laying hens. Hens are fed a special diet which contains 10-20% ground linseed. Linseed is higher in omega-3 fatty acids and lowers in saturated fatty acids than other grains. As a result, the eggs produced from hens on this food formula are higher in omega-3 fatty acids. El-Yamany *et al*. (2008) found the replacement of different levels of linseed oil, sunflower oil and olive oil from poultry fat in Japanese quail diet enhanced ($p<0.05$) plasma total protein, albumen and globulin compared with control diet. These results contribute with the improving of performance and digestibility coefficients. The positive improvement of these values may be due to the inclusion of these oils on fatty acids which may affect muscle protein synthesis and protein deposition through a prostaglandin depend mechanism (Palmer, 1993). Basmacoglu *et al*. (2003) noted that the addition of linseed and fish oil to laying hens diet did not cause any negative effect on some quality criteria such as egg weight, yolk weight, albumen weight, shell weight, shell strength and shell thickness. Da Silva *et al*. (2009) reported that supplementation the quail diet with linseed at levels of 1.5, 3.0 and 5.0% resulted in significant increase in n-3 fatty acid level when compared to that of control group. However, the n-6/n-3 decreased from 21:30 (control group) to 4.52 (5.0% linseed group), which is a better value from the nutritional viewpoint.

Albumen percentage was affected by linseed supplementation. Treated quail hens produced eggs with higher percentage of albumen than did control quail hens during the entire trial. The addition of linseed to the diet of these quail hens did not significantly decrease yolk percentage, but it was numerically less compared to control group. Schideler and Froning (1996) reported similar changes in the proportion of albumen to yolk in laying hens. The decrease in yolk percentage in these eggs is important to consumers because of total cholesterol in the yolk. Decreasing the relative amount of yolk and increasing albumen would decrease the total cholesterol content of the egg. Previous reports have also noticed decreases in percentage egg yolk with addition of linseed or other n-3 fatty acid-supplying feedstuffs. Cherian (2008) observed significant decrease in yolk percentage, shell weight and yolk color for high n-3 group (3.5% fish oil) when compared with low n-3 group (1.75% fish oil + 1.75 yellow grease). Bean and Leeson (2003) found that yolk percentage was reduced ($p<0.05$) in laying hens fed linseed at the level of 10%. Novak and Scheideler (2001) reported that the significant finding in their research was the production of an egg with high levels of n-3 fatty acids, less percentage of egg yolk and a small decrease in yolk solids. The production of an egg with decreased egg yolk percentage may decrease the amount of cholesterol percent per egg consumed. Caston *et al*. (1994) showed decreases in yolk percentage when a 10 or 20% linseed diet was fed to laying hens only from 39-43 wk of age.

Overall, in the light of the results of present experiment the adding of linseed at levels of 2%, 4%, or 6% to the diets of laying quails resulted in improvement in the major part of egg quality parameters included in this experiment. In general it can be recommended that the use of linseed at levels mentioned above in Japanese quail diet during the laying period get higher income efficiency without adverse effect on performance and ameliorate the most of egg quality criteria.

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