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# A review: Effect of linseed oil supplementation on internal and external quality of hen's egg

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**Abstract**
Linseed oil, also known as flaxseed oil or flax oil, is a colourless to yellowish oil obtained from the dried, ripened seeds of the flax plant (*Linum usitatissimum*). Linseed, are rich in LNA (alpha linolenic acid), a precursor of fatty acids like EPA and DHA. The enrichment of layer feeds with oilseed, such as linseed promotes the rapid incorporation of omega-3 fatty acid into the yolk. EPA and DHA are long chain fatty acid which prevents the occurrence of cardiac problems and helps in retinal, mental and overall development of fetus. Considering the potential health benefits of n-3 PUFA, these should be increased in the human diet. The supply of n-3 PUFA can be increased in the animal food sources that the people consume in sufficient amounts. In this regard, poultry eggs are a good source of n-3 PUFA because they can be fortified with n-3 PUFA very easily by dietary supplementations to the laying hens. The enrichment of laying-hen rations with vegetable oils such as linseed or canola, can readily promote the deposition of n-3 PUFA into egg yolk.

**Keywords:** linseed, EPA, DHA, n-3 fatty acid

## Introduction
India's poultry sector represents one of the biggest success stories of the country over the past decade. Livestock sector contributes approximately 4 percent to gross domestic production (GDP) and 27 percent to agriculture GDP. Poultry and dairy sectors are the major sectors contributing to economic development. As per estimates of 19th All India livestock census, the total poultry population in the country has increased by 12.39 percent over the previous census.

Poultry farming has undergone a paradigm shift in structure and operation, transforming itself from a mere backyard activity into a major commercial venture. India is emerging as the world`s 2nd largest poultry market with an annual growth of more than 14%, producing 78.48 billion eggs and 3.04 million tonnes of broiler meat per year, according to estimates of the Ministry of finance, Govt. of India,2014-15. The annual growth rate of egg production is 5-8%. The market is estimated to be worth about 350 billion rupees. Nearly 20 million farmers are employed in poultry industry with around 1,000 hatcheries operating across India. (Anonymous, 3rd International poultry livestock expo, 2014).

Poultry contributes to 15% of the total food energy and 5% of the dietary protein. The per capita consumption per year is 63 eggs (Ministry of finance, Govt. of India, 2014-15), which is much lower than the National Institute of Nutrition`s recommendations of 180 eggs.

Eggs are considered as an important part of human food since the dawn of recorded history. Good taste and numerous applications in preparing a wide variety of foods lead to increase the egg consumption in the world year after year. The egg functional proteins have been recognized as one of the highest quality proteins in digestibility as well as amino acid composition. Hen's egg have been documented as a source of essential fatty acids, and several vitamins and minerals thus, daily intake of hen eggs supply adequate amount of recommended daily allowance of such materials. These advantages qualify hen eggs to be one of the promising functional foods in the coming decades according to their relation to the human health. Although egg is considered a functional food (Stadelman, 1999) [50] and is an excellent source of protein, essential lipids, vitamins and minerals (Zeidler, 2002) [58], many people decrease their consumption of eggs because they consider that high egg cholesterol content may result into cardiovascular diseases.

Over the last three decades, many researchers have been trying to reduce the egg cholesterol content by genetic selection, inclusion of drugs in the ration or by dietary manipulation of hen's diet, but the success was limited.

Recent efforts have been focused on increasing the n-3 polyunsaturated fatty acids (PUFA) content of eggs by the inclusion of dietary sources of these fatty acids into the hens' ration (Hargis and Van Elswyk, 1993) [25]. The n-3 PUFA have many beneficial effects on human health which include, among others, reduction in plasma triglycerides, blood pressure, platelet aggregation, thrombosis and atherosclerosis, tumour growth, skin disease and auto immune disorders (Simopoulos, 1991) [46]. The n-3 PUFA can also play a vital role in lowering blood cholesterol concentrations (Simopoulos, 2000) [47]. It is recommended that n-3 PUFA should be at least 0.5 percent of the energy intake or 1.1 gas Linolenic acid (LNA; 18:3 n-3) per day for an individual consuming 2,000 Kcal. It has been suggested that the daily intake of 0.5 to 1.0 g of n-3 PUFA in diet reduces the risk of cardiovascular disease (Simopoulos, 1991) [46].The recommended ratio of n-6/n-3 PUFA is 4 to 10:1 in the human diet (Nutrition recommendations, 1990)[33].

Oil plants and some legumes can serve as source of oils to be used for supplementation of diets for poultry. Due to increasing public demand for animal products low in fat and cholesterol, studies have been focusing on improving the quality of foods from animal origin. Cholesterol and fatty acid concentrations of egg yolk vary depending on dietary manipulation and pharmacological agents as well as genetics, age and production level of bird. Concerning nutrition, one of the methods developed to change the lipid profile of eggs has been the use of different oil sources that are commonly used as energy sources in the diets of laying hens (Baucells *et al.*, 2000; Grobas *et al*., 2001) [7, 23]. In the production of eggs rich in n-3 fatty acids, there is increasing interest in maximizing the use of feed stuff containing these nutrients because there is a correlation between their levels in feed and in the yolk (Leeson *et al*., 1998) [31].

**Egg Production**

Linseed oil had no effect on laying performance of hens when supplemented at the level of 2, 4 and 6 % of the diet; egg production was similar in all laying hens either receiving diet with linseed oil or diet with no linseed oil (Jiang *et al*., 1991b) [29]. Reduction in egg production by feeding linseed has only been observed for young birds early in their reproductive cycles (Van Elswyk, 1997b) [54]. Yannakopoulos *et al*. (1999) [57] reported that diets with 10 or 20% flaxseed had no influence on egg production. Schumann *et al*. (2000) [41] found that egg production reduced continuously as the trial proceeded, in which 4 % linseed oil was fed to the hens. Galobart *et al*. (2001) [20] and Grobas *et al*. (2001) [23] reported that the hens fed 5 or 10 % linseed oil produced similar number of eggs when compared to the hens without supplementation during a laying period of 12 weeks. Novak and Scheideler (2001) [32], and Bean and Leeson (2003) [8] also reported that egg production was not significantly ($P< 0.05$) different for the hens fed 10% flax seed compared to those on the diet with 0 % flaxseed. Beynen (2004) [9] found an increase in egg production in hens fed linseed when compared to the reference diet. While, Celebi and Utlu (2006) [12] demonstrated an increase ($P < 0.05$) in the egg production of hens fed 4 % linseed oil in the diet. The increase in dietary fat content (by adding linseed and linseed oil) in hens' diet increased the egg production up to 4 % (Augustyn *et al*., 2006) [3]. On the other hand, Ansari *et al*. (2006) [2] indicated that the 15% flaxseed in the diet was associated with a decrease in egg production in the hens. Silke *et al*. (2008) [44] added two dietary fats (soybean oil and linseed oil) in the ration of laying hens and reported no difference in egg production in layers in different treatment groups. Švedová *et al*. (2008) [52] also observed a decrease in egg production in hens fed 3 % linseed oil. Aziza *et al.* (2013) [6] reported that egg production increased significantly ($P < 0.05$) by supplementing 10% flaxseed meal.

**Feed intake and feed efficiency**

Schumann *et al*. (2000) [41] observed no change in feed intake in laying hens at the diet with 4 % linseed oil. Crespo and Esteve-Garcia (2001) [15] showed that feeding linseed oil 5 or 10 % of the diet reduced the feed intake with improved feed efficiency in broiler chickens. While, Novak and Scheideler (2001) [32] reported an increase in feed intake in hens given the flaxseed in the diets. Grobas *et al*. (2001) [23] found that the hens fed 5 or 10 % linseed oil showed a decrease in feed intake with improved feed efficiency (Kg feed/kg egg and kg feed/dozen eggs). Crespo and Esteve-Garcia (2002)[16] fed 10 % linseed oil to the broilers and established that n-3 PUFA may not change feed intake of birds but can improve feed efficiency significantly. Contrarily, Raes *et al*. (2002) [38] pointed out reduced feed intake but with improved feed efficiency in hens kept on diets with linseed oil fortification. Bean and Leeson (2003) [8] demonstrated that feed intake was reduced ($P < 0.05$) for the hens fed 10% flax seed. In another trial, the feed intake of the hens receiving diets supplemented with 4 % linseed oil was lower ($P < 0.05$) than the hens in the control group with no change in feed efficiency (Celebi and Utlu, 2006) [12]. The 15% flaxseed level was related with increase in feed conversion ratio in the laying hens (Ansari *et al*., 2006) [2]. The inclusion of linseed oil in experimental diets decreased feed intake up to 14 %with an improved feed efficiency (Augustyn *et al*., 2006) [3]. Haug *et al*. (2007) [26] reported that rapeseed oil or rapeseed oil plus linseed oil did not influence feed intake or feed conversion ratio in broilers. The supplementation of linseed oil at the level of 3 % in the diet did not produce any visible effect on feed intake of broiler birds (Fébal *et al*., 2008) [18].

Faqir Muhammad Anjum *et al.* (2013) [17] revealed that the supplementation of extruded flaxseed in the diet decreases the body weight gain, feed intake and increased feed conversion ratio (FCR) in broilers. Ahmad *et al.* (2013) [1] demonstrated that egg production and feed intake decreased, while feed conversion ratio (FCR) per dozen of eggs increased ($P<0.05$) with increasing dietary linseed levels.

**Egg characteristics in laying hens**

**Egg weight and egg mass**

The reports on the effect of linseed on egg weight and egg mass in laying hens are variable to a great extent. Many reports showed no effect of dietary oils rich in n-3 PUFA on egg weight. Yannakopoulos *et al*. (1999) [57] indicated that diet with 10 or 20% flaxseed had no influence on egg weight in laying hens. Schumann *et al*. (2000) [41] also observed no change in egg weight in laying hens at 4 % linseed oil in the diet. Galobart *et al*. (2001) [20] reported similar egg weight in the hens fed 5 % linseed oil as compared to the controls. Novak and Scheideler (2001) [32] noted that egg weight and egg mass did not change by feeding 10 % linseed to hens. Grobas *et al*. (2001) [23] showed that the hens fed 5 or 10 % linseed oil produced eggs without any change in egg weight or egg mass during a period of 12 weeks. Linseed oil in the diet of layers did not affect egg weight and egg mass (Raes *et* *al*., 2002) [38]. Beynen (2004) [9], and Sosin *et al*. (2006) [48] reported that feeding linseed to hens decreased ($P < 0.05$) egg weight. On contrary Eggs from birds provided with linseed oil in their diet were 4 % smaller then the control eggs (Augustyn *et al*., 2006) [3]. Feeding 4 % linseed oil in the feed has no *effect* on egg weight of the hens (Celebi and Utlu, 2006) [12]. Silke *et al*. (2008) [43] found that dietary fats (soybean oil and linseed oil) had no effect on egg weight in laying hens. However, Švedová *et al*. (2008) [52] observed an increase in egg weight in hens fed 3 % linseed oil. Hazim J. AI-Daraji *et al*. (2010) [27] reported that 2, 4 and 6% linseed supplementation significantly ($P < 0.01$) increased the egg weight. Aziza *et al.* (2013) [6] concluded that feeding flaxseed meal and camelina at the level of 10% with a corn-soybean basal diet (control) significantly ($P < 0.05$) decreases egg weight.

**Eggshell Quality**

Inclusion of linseed into the diet of laying hens can deteriorate eggshell quality in terms of shell weight (Van Elswyk, 1997b) [54]. Shell quality, in terms of shell thickness and shell strength, is a significant factor in egg appearance, as well as being very important in egg handling. A recent report by Patterson *et al*. (2001) [36] indicated greater egg breaking and leakage in specialty eggs enriched with n-3 PUFA when compared with regular eggs. Novak and Scheideler (2001) [32] observed that flaxseed fed hens produced eggs with reduced wet shell percentage. Other researchers found no effect of feeding diets rich in n-3 PUFA on eggshell quality. Galobart *et.al*. (2001) [20] reported that egg shell thickness remained similar in the hens fed 5 % linseed oil as compared to the controls. Grobas *et al*. (2001) [23] demonstrated that the hens fed 5 or 10 % linseed oil produced eggs with unchanged shell weight but with reduced shell thickness. Linseed oil in the ration of layers did not produce any visible change in egg shell quality and shell weight (Raes *et al*., 2002) [38]. In a study by Bean and Leeson (2003) [8], eggshell thickness remained unchanged by feeding flaxseed. Hazim J. AI-Daraji *et al*. (2010) [27] reported that 2, 4 and 6% linseed supplementation significantly ($P < 0.01$) increased the shell thickness. Aziza *et al.* (2013) [6] studied the effect of feeding flaxseed meal and camelina at the level of 10% with a corn-soybean basal diet (control) on performance and egg quality of layers and reported that the egg production increased significantly ($P < 0.05$) compared with the control. The egg weights and Haugh units increased, and eggshell thickness decreased significantly ($P < 0.05$) in birds fed with flaxseed meal. Ahmad *et al.* (2013) [1] demonstrated that egg shell thickness and shell weight is not affect by linseed feeding.

**Yolk index and yolk percentage**

Scheideler and Froning (1996)[39] found a decrease in egg yolk size of hens from hens fed 5 to 15 % flaxseed and 1.5% fish oil and suggested that these results were due to the effect of PUFA on the estrogen activity of the hen.Similarly, Scheideler *et al. (*1998) [40] reported that flaxseed had no significant effect on wet yolk percentage. Novak and Scheideler (2001) [32] also observed that there was a reduction in wet yolk percentage produced by linseed fed hens. Hens fed flaxseed produced eggs with a smaller ($P < 0.05$) percentage of wet yolk compared to the control birds (Bean and Leeson, 2003) [8]. Hazim J. AI-Daraji *et al*. (2010) [27] reported that 2, 4 and 6% linseed supplementation significantly ($P < 0.01$) increased the yolk diameter. Ahmad *et al.* (2013) [1] demonstrated that yolk weight not influenced ($P< 0.05$) by linseed.

**Egg white quality**

Jiang *et al*. (1991b) [29] found no change in haugh unit value in the hens fed linseed enriched diets. Similarly, Scheideler *et al*. (1998) [40] found no effect of feeding flaxseed on the egg white percentage of the eggs. Grobas *et al*. (2001) [23] revealed that the hens fed 5 or 10 % linseed oil produced eggs with no change in haugh unit value but with an increase in albumin weight when compared to the hens without supplementation. Novak and Scheideler (2001) [32] also observed that there was a significant increase in albumin percentage in eggs produced from hens fed linseed. Galobart *et al*. (2001) [20] reported no change in haugh unit value in the hens fed 5 % linseed oil. Albumin quality in terms of weight % of egg was not affected by dietary linseed oil fed to laying hens (Raes *et al*., 2002) [38]. Whereas the eggs from hens fed linseed or linseed oil had less albumin than control eggs (Augustyn *et al*., 2006) [3]. Hazim J. AI-Daraji *et al*. (2010) [27] reported that 2, 4 and 6% linseed supplementation significantly ($P< 0.01$) increased the albumin height and haugh unit.

**Egg yolk fatty acids**

The n-3 PUFA of the eggs can be significantly increased by feeding linseed to laying hens (Aymond and Elswyk, 1995)[5].The hens fed on diets with linseed produced eggs with n-3 PUFA contents in the following order: LNA>DHA>DPA>EPA (Sim and Qi, 1995)[45]. This indicates that laying hens can convert dietary LNA to EPA, DPA and DHA via the desaturase and elongase enzyme system (Garg *et al*., 1988) [22].Van Elswyk (1997) [53] conducted a study that found as dietary linseed increased, total yolk n-3 PUFA increased in a linear fashion. He also reported that feeding 15 % ground linseed in the diet resulted in a 2-3 mg/yolk greater incorporation of EPA and DPA than the control diet. Linseed is one of the most concentrated sources of linolenic acid (LNA) available in vegetable feedstuff for poultry (Scheideler *et al*., 1998) [40]. Studies show that with linseed or linseed oil feeding, the major n-3 fatty acid incorporated into egg yolk was LNA although significant amounts of DPA and DHA are also deposited (Scheideler and Froning,1996; Bean and Lesson, 2003) [39, 8]. It has been reported that humans have limited ability to convert LNA to EPA and DHA so eggs should be considered a valuable dietary source of DHA for humans (Baucells *et al*., 2000) [7]. Arachidonic acid was significantly reduced with the inclusion of linseed in hens' feed which resulted into the decreased ratio of n-6 to n-3 PUFA in the n-3 PUFA enriched eggs (Sim and Qi, 1995) [45]. In a study conducted by Goncuglu and Ergun (2004)[[22], feeding laying hens with linseed oil at 0, 1, 2, 3 and 4 % of the diet led to significant increase in n-3 and n-6 PUFA of yolk. In a study by Ansari *et al*. (2006) [2], linseed supplementation ( 0, 5, 10, and 15 % of the diet) did not affect yolk total fat content at any level, however, saturated fatty acids were decreased and unsaturated fatty acids were increased linearly with the increase in dietary linseed content.

The inclusion of 20 % linseed in the ration of laying hens increased the n-3 PUFA in the egg yolks, mainly LNA and EPA (Pita *et al*., 2006) [37]. Inclusion of flaxseed into hens' diet notably altered egg fatty acid composition; total PUFA were significantly increased (Egg LNA increased linearly as the ground flaxseed increased from 5 to 10% in the diet), whereas monounsaturated fatty acids (MUFA; mainly oleic acid) were significantly decreased. This decrease was less pronounced in treatments when a significantly higher n-6 to n-3 PUFA ratio occurred (Botsoglou *et al*., 1998) [10]. Therefore, the n-6 to n-3 PUFA ratio is an important factor for the deposition of oleic acid (Garg *et al*., 1988) [21]. According to Yalcyn *et al*. (2007) [56], feeding linseed and linseed oil have a tendency to decrease total saturated fatty acid content of the egg. They also added that linseed @ 8.64 % in the diet of laying hens increased n-3 PUFA of egg yolk significantly, with a major increase in LNA content.

Galobart *et al*. (2001) [20] reported a reasonable increase in n-3 PUFA especially LNA in the egg yolk of hens fed 5 % linseed oilas compared to the controls. Cherian and Sim (1997) [14] demonstrated that the increase in n-3 PUFA in eggs of laying hens fed on linseed oil was mainly by LNA. Grobas *et al*. (2001) [23] concluded that 5 or 10 % linseed oil increased the egg yolk PUFA contents at the expense oleic acid in the hens; the increase in n-6 PUFA was due to the increase in LA, whereas the increase in n-3 PUFA was due primarily to an increase in LNA. Ferrier *et al*. (1995) [19] calculated that one egg from a hen fed a diet containing 10 % linseed can supply 30 % of the daily need (1.1 to 1.5 PUFA per day) of total n-3 PUFA; such an egg provides about 264 mg LNA, 10 mg EPA and 82 mg DHA. Feeding the linseed diet resulted in eggs with the highest level of LNA, EPA and DHA, and the lowest content of LA when compared to reference diet or diets with soybean or ground nut (Beynen, 2004) [9].

Shapira *et al*. (2008) [43] concluded that in n-3 PUFA-fortified eggs (with 5 % linseed in feed), the concentration of total n-3 PUFA increased to 3.8-fold that of control eggs, LNA to 6.8-fold, and DHA to 2.4-fold and total n-6: n-3 PUFA ratio was decreased 3.6-fold from the control. Souza *et al*. (2008) [49] were able to record a linear increase in n-3 PUFA content of egg yolk with the increase in linseed oil from 0 to 2 % of the diet. T. Sujatha and D. Narahari (2011) [51] studied the effect of designer diet on egg yolk composition of white leghorn hens. They divided birds into four groups Control (without enrichment); FSE − (150 g flaxseeds + 200 mg vitamin E + 3 g spirulina/kg diet); FOSe (20 g fish oil + 0.2 mg organic Se (Sel-Plex) + 3 g spirulina/kg diet) and FSE + FOSe (75 g flaxseed + 10 g fish oil + 100 mg vitamin E + 0.1 mg organic Se + 3 g spirulina/kg diet). All three designer diets increased ($P < 0.01$) the yolk carotenoid pigments and omega-3 fatty acid levels ($P < 0.05$) with proportionate reduction in saturated fatty acid levels and no significant change in the oleic acid levels in the yolk lipids. The three diets also reduced ($P < 0.01$) the yolk cholesterol levels. Souza *et al. (*2008) [49] investigated that replacing soyabean oil (2%) with linseed oil (0.0, 1.0, 1.5, 2.0%) resulted in significant ($P<0.05$) increase in the concentration of PUFA in the egg yolk. Saturated fatty acid content (myristic and palmitic fatty acids) was influenced ($P<0.05$) with lower concentrations in the eggs of layers fed diets containing only linseed oil.

Oliveira *et al.* (2010) [34] concluded that hens fed the diet containing linseed oil had the highest percentage of n-3 PUFA and n-6:n-3 ratio of 2.01.Kirubakaran A. *et al.* (2011) [30] conducted a study to investigate the Effects of flaxseed, sardines, pearl millet, and holy basil leaves on production traits of layers and fatty acid composition of egg yolks and reported that the flaxseed oil significantly increased n-3 polyunsaturated fatty acid levels in the egg yolks, with a proportionate reduction in the level of palmitic acid.

Petra Hudeckova *et al.* (2012) [28] observed that replacing soyabean oil with linseed oil resulted insignificantly ($P < 0.05$) higher concentration of myristic acid. Similarly Highly significant differences ($P < 0.01$) were found for n-9 monounsaturated fatty acids where egg yolks in eggs from layers fed linseed oil contained higher concentrations of oleic acid, myristoleic acid, and palmitoleic acid. Lower concentrations of n-6 fatty acids ($P < 0.01$) were found after the addition of linseed oil in eggs. Linseed oil showed a positive effect on n-3 fatty acids (α-linolenic acid), its concentration in the control and experimental group was 0.82 g/100 g of fat and 5.63 g/100 g of fat, respectively.

Haechang *et al.* (2014) [24] studied Fatty Acid Composition and Sensory Characteristics of Eggs Obtained from Hens Fed Flaxseed Oil, Dried Whitebait and/or Fructo-oligosaccharide. The hens were fed a basal diet with 1.5% soybean oil (control), 1.5% flaxseed oil (T1), 1.5% soybean oil+ 1.5% FOS (T2), 1.5% flaxseed oil+1.5% FOS (T3), 1.5% soybean oil+1.5% dried whitebait (T4), 1.5% flaxseed oil+ 1.5% dried whitebait (T5) or 1.5% flaxseed oil+1.5% dried whitebait+1.5% FOS (T6). And found that flaxseed oil increases the ALA content in the eggs and Egg cholesterol.

Omar *et al.* (2014) [35] concluded that diets containing FO, LO, and their combinations resulted in a significant increase of n-3 polyunsaturated fatty acids and polyunsaturated fatty acid concentrations in eggs compared to the control group. Adding 2% FO, 1% FO + 1% LO and 1.5% FO + 1.5% LO to laying diets decreased ($P < 0.05$) egg yolk total cholesterol and egg yolk total lipids compared to control groups. The lowest values of egg yolk total cholesterol and egg yolk total lipids were recorded by 1.5% FO + 1.5% LO compared to other treatments. Cherian and Quezada (2016)[13] investigated the Egg quality, fatty acid composition and immunoglobulin Y content in eggs from laying hens fed full fat camelina or flax seed at the level of 10% for a period of 16 weeks. They reported that significant increase in α-linolenic (18:3 n-3), docosapentaenoic (22:5 n-3) and docoshexaenoic (22:6 n-3) acids were observed in egg yolk from hens fed Camelina and Flax. Total n-3 fatty acids constituted 1.19 % in Control eggs compared to 3.12 and 3.09 % in Camelina and Flax eggs, respectively ($P < 0.05$).

**Egg Cholesterol**

Watkins and Elkin (1992) [55] did not find any change in egg cholesterol concentration with olive oil, soybean oil or tallow supplementation. Feeding of linseed and linseed oil resulted into an increase in egg cholesterol contents up to 291 mg per egg. Caston and Leeson (1990) [11] and Scheideler and Froning(1996)[39] could not find any reduction in egg cholesterol in hens fed linseed in the diets. Yolk cholesterol was not responsive to dietary manipulation of 5 or 10 % linseed in a study by Botsoglou *et al*. (1998) [10]. Ayerza and Coates (2000) [4] reported that significantly lower ($P < 0.05$) yolk cholesterol was found with chia (a rich source of n-3 PUFA) diets fed to hens. Shafey *et al*. (2003) [42] investigated the relationship between type of oil supplement and blood and egg yolk cholesterol. They found that dietary type of oil supplement changed the fatty acid composition of egg yolk and composition of plasma lipoproteins without having a significant effect on the overall egg yolk content of triglyceride and cholesterol. Beynen (2004) [9] could not find any reduction in egg cholesterol in hens fed linseed in the diets. Ansari *et al*. (2006) [2] found that yolk cholesterol decreased linearly with the increase in the level of flaxseed in the diet and the highest yolk cholesterol, content was seen in the control group. Yalcyn *et al*. (2007) [56] reported that no consistent evidence was provided by the feeding linseed in the hens' diet to support the yolk cholesterol lowering effect of dietary n-3 PUFA except with a higher level of linseed (8.64 %). The authors' hypothyzed that the decrease in cholesterol could arise because of the crude fibre content of the diet as the diet contained the highest crude fibre of all the diets used in the trial. Shapira *et al*. (2008) [43] concluded that in n-3 PUFA-fortified eggs (with 5 % linseed in feed) the average cholesterol content was not different significantly from the controls.

**Economics of feeding linseed oil**

Omar *et al*. (2014) [35] investigated that using 1% fish oil only or 1% fish oil + 1% linseed oil in laying hen diets improved the economical efficiency comparable to the control group. The best feed cost/kg egg was recorded by the group fed diet 1% Fish oil + 1% Linseed oil.

**Conclusion**

Linseed oil supplementation improves the performance of laying hens. It helps in increasing the level of omega-3 – fatty acids in the egg yolk, which are beneficial for human beings. Decreases cholesterol level in egg yolk.

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