ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF

POULTRY SCIENCE

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International Journal of Poultry Science 10 (10): 825-831, 2011
ISSN 1682-8356

Effect of Adding Flaxseed in the Diet of Laying Hens on Both Production of Omega-3 Enriched Eggs and on Production Performance

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Abstract: Since eggs are an important part of the human diet and people have strong health awareness, it is beneficiary to produce eggs that are considered healthier products such as omega-3 enriched eggs. Omega-3-fatty acids have been shown to improve the human health in many aspects. Lowering circulating levels of cholesterol and lowering blood pressure are just some of their effects. It has been shown that feeding laying hens with flaxseeds leads to an increase levels of omega-3-fatty acids in the eggs and change the Omega-6 to Omega-3 ratio to an appropriate one. However, studies on the effects of feeding flaxseed to laying hens on both increase levels of omega-3 fatty acids and production performance are limited. Therefore, the purpose of the current study was to study the effects of adding flaxseed in the diet of laying hens on both producing omega-3 enriched eggs and on the production performance. Twenty four wk old Lohmann Selected Line (LSL) laying hens were used in the current study. The hens were divided randomly into four groups, the first received a diet with no flaxseed added and served as a control, the second, third and fourth group received 5.0%, 7.5% and 10% of flaxseed in the diet, respectively. The treatments continued for 32 wks. Egg production and feed consumption were recorded and feed efficiency was calculated. In addition, eggs from the different groups were collected at four, eight and 32 wks following treatment and levels of omega-3 and omega-6 fatty acids were measured and the ratio between the two was calculated. At eight wks following treatment, it was found that using either 7.5 or 10% flaxseed in the diet significantly ($p<0.05$) increased levels of omega-3 fatty acids in the eggs compared to the control. Levels were 267, 232 and 64 mg/egg for the 10%, 7.5% and control group, respectively. In addition, ratio of omega-6 to omega-3 was 2.33:1, 2.98:1 and 10.05: 1, for the same groups, respectively. Furthermore, adding flaxseed in the diet did not adversely affect egg production, egg weight, or feed efficiency. It can be concluded that using flaxseed in the diet of laying hens can result in producing omega-3 enriched eggs and reducing the omega-6: omega-3 ratio without any adverse effects on production performance.

Key words: Laying hens, flaxseed, omega-3 fatty acids, production parameters

INTRODUCTION

The major components of the poultry industry in Kuwait include both table egg and broiler production. As to the table egg industry, there are approximately 2 million hens that are raised annually producing approximately 480 million eggs per year valued at approximately 13 million KD ($45 million). Even though the egg industry is one of the most important animal industries in Kuwait, yet the local industry covers approximately 60 % of local consumption (Razzaque and Al-Nasser, 2003) and the remaining is imported because of the lower price of imported eggs. It is important to note that eggs are a major food item in Kuwaiti meals and per capita egg consumption in Kuwait is 240 eggs/year which is higher than that in the regional countries and comparable to that in the USA. However, since the egg industry does not necessarily cover all local consumption, it is important that the local table egg industry works on further improvement of production efficiency and production of unique products in order for the egg industry to be able to compete in the local market not only in prices but also in quality and uniqueness of products. Even more importantly since there is a constant increase in health awareness of the people of Kuwait, producing unique and healthy poultry products is essential and required. These healthy and unique products could be eggs that have much higher levels of omega-3-fatty acids than that in standard eggs.

Omega-3-fatty acids have been shown to improve the human health in many aspects. Omega-3 fatty acids have been shown to be involved in the prevention of general cardiovascular diseases (Defilippis *et al*., 2010; Carrillo-Fernandez *et al*., 2011; Fernandez *et al*., 2011) and prevention of coronary heart diseases (Stampfer *et*

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al., 2000; Jarvinen *et al*., 2006). These fatty acids have also been shown to reduce both hypertension (Prisco *et al*., 1998; Appel, 1999) and hypercholesterolemia (Prasad, 1997). Not only that but also Omega-3 fatty acids have been shown to reduce level of serum triglycerides (Von Schacky, 2006). In addition, omega-3 fatty acids were found to help in reducing inflammation (Belluzzi *et al*., 2000; Hao *et al*., 2010), reducing asthma symptoms (Broughton *et al*., 1997), causes stabilization of vulnerable atherosclerotic plaques (Hamer and Steptoe, 2006), have benefits in kidney diseases (Friedman, 2010), have an effect on immunomodulation (Iwami *et al*., 2011) and significantly increase level of human serum lutein (Burns-Whitmore *et al*., 2010). Furthermore, omega-3 fatty acids were used to treat depression disorders and attention-deficit/hyperactivity disorder (Bruinsma and Taren, 2000; Laino *et al*., 2010), reduce postpartum depression (Grigoriadis *et al*., 2010).

In addition, maintaining an appropriate ratio between omega-6 and omega-3 has been reported to be important for health benefits (Wahrburg, 2004) and was also proposed as a biomarker of risk for coronary artery disease (Harris *et al*., 2006). Simopoulos (2002) reported that the western diet is deficient in omega-3 fatty acids with a ratio of omega-6 to omega-3 from 15-20/1 instead of the approximately 4/1 ratio recommended by WHO and FAO (1995) and 5/1 as reported by Kouba and Mourot (2011). Simopoulos (2002) also mentioned that a lower ratio of omega-6/omega-3 fatty acids is more desirable in reducing the risk of many of the chronic diseases. Simopoulos (2011) indicated that a lower ratio is important for homeostasis and normal development throughout the life cycle. De Logeril *et al*. (1994) reported that a ratio of 4:1 of omega-6 to omega-3 fatty acids in the diet helped in secondary prevention of coronary heart disease. In addition, Riediger *et al*. (2009) reported that low ratio of omega-6 to omega-3 fatty acids reduces cardiovascular and metabolic risks. Furthermore, Raheja *et al*. (1993) reported that a ratio of 6:1 of omega-6 to omega-3 fatty acids in the diet decreased the prevalence of non-insulin-dependent-diabetes mellitus. In addition, lower ratio of omega-6 to omega-3 fatty acids in the diet improve glucose tolerance (Smith *et al*., 2010), reduces disturbance in glucose metabolism (Sartorelli *et al*., 2010) and has a potential therapeutic merit in type 1-diabetes. Furthermore, James and Clelsnd (1997) reported beneficial effects in patients with rheumatoid arthritis when a diet that contained a ratio of 3-4:1 of omega-6 to omega-3 fatty acids was used. Low ratio of omega-6 to omega-3 was found to reduce proinflammatory cytokines (Cotogni *et al*., 2011), reduces atherosclerosis (Wan *et al*., 2010) and in general has an anti-inflammatory effect (Hagi *et al*., 2010).

Therefore, it is clear that production of unique eggs that contains a high level of omega-3-fatty acids and appropriate ratio of omega-6 to omega-3 fatty acids is important to be included in a healthy diet since they will have significant health benefits.

Production of such unique and healthy omega-3 enriched eggs can be accomplished by adding flaxseed in the diet of the laying hens. Scheideler and Froning (1996), Lewis *et al*. (2000) and Bean and Leeson (2003) reported an increase in levels of omega-3-fatty acids in eggs using flaxseed in the diet of the laying hen. In addition, the general benefits of flaxseed have been reviewed (Singh *et al*., 2011).

Studying the effects of feeding flaxseed to the laying hens on production performance is important since these unique eggs will be produced commercially and these criteria are important for the financial benefits of the commercial poultry producers. Bean and Leeson (2003) found that egg production and egg quality were not significantly different in the hens fed flaxseed compared to control hens. In addition, Novak and Scheideler (2001) found that feeding flaxseed not only did not adversely affect percent egg production of laying hens but resulted in heavier eggs than the control hens. Furthermore, Scheideler and Froning (1996) and Scheideler *et al*. (1998) found that feeding flaxseed to laying hens improved egg production. These findings indicate that feeding flaxseed to laying hens that will result in producing omega-3 enriched eggs which are a healthy product, could also improve egg production and egg weight.

However, studies on the effects of feeding flaxseed to laying hens on both increase levels of omega-3 fatty acids and also on the production performance are limited. Therefore, the purpose of the current study was to investigate the effects of adding flaxseed in the diet of laying hens on both producing omega-3 enriched eggs and on production performance.

MATERIALS AND METHODS

The hens that were used in the current experiment were Lohmann Selected Line (LSL) and were received as one-day-old pullets and were housed first in pullet cages. At eighteen weeks of age, the hens were moved and were housed in laying hen cages. Three hens were housed in each cage and the cage was measured at 41-cm width and 30-cm depth with 410 cm^2/hen. The hens received 14 h of light/day and duration of light remained the same thereafter until the end of the experiment. Treatments started when the hens were 24 weeks of age and lasted for 32 weeks. At 24 weeks of age the hens were randomly divided into four treatment groups, the first received a diet with no flaxseed added in the diet and served as a control, the second, third and fourth groups received 5.0%, 7.5% and 10% of flaxseed in the diet, respectively. The diet formulations for the four

Table 1: Formulation and calculated analyses of laying hen diets containing different levels of flaxseed

Ingredient	Control 0% Flaxsed	5% Flaxseed	7.5% Flaxseed	10% Flaxseed
Corn	503.00	483.47	475.47	468.47
Soybean meal	260.47	236.00	224.00	212.00
Flaxseed	0.00	50.00	75.00	100.00
Wheat bran	65.00	65.00	65.00	65.00
Soya oil	58.00	52.00	47.00	41.00
Limestone	89.00	89.00	89.00	89.00
DiCalcium phosphate	15.00	15.00	15.00	15.00
Salt	3.13	3.13	3.13	3.13
DL-methionine	1.40	1.40	1.40	1.40
Layer premix*	5.00	5.00	5.00	5.00
Total	1000.00	1000.00	1000.00	1000.00
Nutrient composition				
Calculated analysis				
Crude protein (%)	18.00	18.00	18.00	18.00
Metabolizable energy (kcal/kg)	2900.00	2900.00	2900.00	2900.00
Calcium (%)	3.80	3.80	3.80	3.80
Phosphorus Avi (%)	0.40	0.40	0.40	0.40
Sodium (%)	0.15	0.15	0.15	0.15
Lysine (%)	0.98	0.98	0.98	0.98
Methionine (%)	0.44	0.44	0.44	0.44
Choline (mg/kg)	1107.00	1080.00	1080.00	1070.00

*Supplied per kg of diet: trans-retinol (A), 2000000IU; cholecalciferol (D3), 400000IU; alpha - tocopherol acetate (E), 3000 mg; thiamine (B1), 200 mg; riboflavin (B2), 1000 mg; pyridoxine (B6), 300; vitamin B12, 3000 mcg; pantothenic acid, 1000 mg; folic acid, 20 mg; Fe, 4000 mg; Co, 1000 mg; Mn, 14000 mg; Zn, 10000 mg; I, 100 mg; Se, 40 mg; Antioxidant added; Ash, 97%

different treatment groups are shown in Table 1. All hens were provided with food and water *ad libitum*.

Production parameters measured and calculated, throughout the experiment, included percent egg production, egg weight, egg mass, feed consumption and feed efficiency. The data for each replicate were collected from four cages (twelve hens) and there were 15 replicates for each treatment for a total of 240 cages (720 laying hens) for the four treatments.

In addition, five eggs were collected randomly from each of the four treatment groups at four, eight and 32 wks following the treatments and levels in the egg yolk of omega-6 and omega-3 fatty acids were measured and the ratios between the two fatty acids were calculated.

One-way analysis of variance, using the General Linear Model (GLM) (SAS Institute, 1996) was used to compare the effect of feeding different levels of flaxseed on production parameters and on the levels of omega-6 and omega-3 fatty acids and the ratio between them. The treatment was the only factor considered and the analysis was done for each laying period separately.

RESULTS AND DISCUSSION

Effects of treatments on levels of omega-6 and omega-3 fatty acids and the ratio between them in the egg yolk: Data on effects of adding different levels of flaxseed in the diet of laying hens on levels omega-6 and omega-3 fatty acids and the ratio between them at four weeks, eight weeks and thirty two weeks following treatments are shown in Table 2, 3 and 4, respectively. Our results show that levels of total of omega-3 fatty acids in eggs from hens that were fed 10% flaxseed, were significantly increased ($p<0.05$) four weeks following the treatment when compared with the control eggs. This level was further increased at eight weeks following the treatment, however, no further increase was observed at thirty two weeks following the treatment. This indicates that maximum increase in the level of omega-3 fatty acids in the egg yolk is reached at eight weeks following feeding 10% of flaxseed. Furthermore, levels of omega-3 fatty acids in eggs from hens fed either 5% or 7.5% flaxseed started to be significantly ($p<0.05$) higher than the control eggs at eight weeks following the treatment and not at four weeks as was the case in the 10% group. Our results agree with the findings of Ferrier *et al.* (1995); Cherian and Sim (2001); Bean and Leeson (2003) and Yannakopoulos *et al.* (2005) who found that adding flaxseed in the diet of laying hens increased level of omega-3 fatty acids in eggs. Furthermore, Grobas *et al.* (2001) found that adding linseed oil to the diet of laying hens also increased level of omega-3 fatty acids in the egg. Our results reemphasize the importance of adding flaxseed in the diet of laying hens on producing omega-3 fatty enriched eggs.

In addition to the advantages of adding flaxseed in the diet of laying hens on increasing levels of omega-3 fatty acids in the egg yolk, Lewis *et al.* (2000) concluded that consuming omega-3 enriched eggs have positive effects with no negative effects. Furthermore, Ansenberger *et al.* (2010) reported on the effects of flaxseed on reducing ovarian cancer. It should be mentioned that consuming two eggs of the current omega-3 enriched eggs would contribute significantly to the daily intake recommended by Institute of Medicine (2002) which is an average of 1.35 g/day and is 900 mg/d/2000 Cal as reported by Hibbeln and Davis (2009).

Table 2: Effect of feeding different levels of flaxseed for four weeks on levels of omega fatty acids in the yolk of 56 g whole egg

	Level of flaxseed in the diet			
Parameter	Control (0%)	5%	7.5%	10%
Total amount of omega-3	79.36±29.83*[ab]	113.68±22.93[b]	145.26±41.64[ab]	174.58±40.8[a]
Amount of omega-6	678.87±103.60[a]	639.47±72.96[a]	663.37±105.74[a]	656.51±168.81[a]
Ratio of omega 6 to 3	9.52±3.39[a]	5.85±1.54[b]	3.65±1.75[b]	3.74±0.26[b]

[ab]Means within the same raw with different letters are significantly different (p<0.05). *Values are means±SD (n = 5)

Table 3: Effect of feeding different levels of flaxseed for eight weeks on levels of omega fatty acids in the yolk of 56 g whole egg

	Level of flaxseed in the diet			
Parameter	Control (0%)	5%	7.5%	10%
Total amount of omega-3	64.23±11.13*[c]	144.26±51.24[b]	231.82±28.71[a]	266.67±58.30[a]
Amount of omega-6	631.31±67.00[a]	575.58±79.96[a]	680.74±92.62[a]	609.68±75.53[a]
Ratio of omega 6 to-3	10.05±01.979[a]	4.46±01.87[b]	2.98±00.58[b]	2.33±00.33[b]

[abc]Means within the same raw with different letters are significantly different (p<0.05). *Values are means±SD (n = 5)

Table 4: Effect of feeding different levels of flaxseed for thirty two weeks on levels of omega fatty acids in the yolk of 56 g whole egg

	Level of flaxseed in the diet			
Parameter	Control (0%)	5%	7.5%	10%
Total amount of omega-3	107.49±10.68*[b]	232.00±30.16[a]	226.01±33.78[a]	251.96±32.76[a]
Amount of omega-6	1253.77±101.22[ab]	1390.30±157.86[a]	1054.63±123.86[b]	1029.88±121.23[b]
Ratio of omega 6 to 3	11.73±1.19[a]	6.00±0.22[b]	4.69±0.23[c]	4.36±0.36[c]

[abc]Means within the same raw with different letters are significantly different (p<0.05). *Values are means±SD (n = 5)

As to the time duration required for the incorporation of omega-3 fatty acids in the eggs following adding flaxseed in the diet of the laying hens, Caston and Leeson (1990) found that omega-3 fatty acids were increased four weeks following flaxseed treatment which is similar to our findings. In addition, Cherian and Sim (2001) reported that only 21 days following feeding flaxseed in the diet of laying hens, omega-3 fatty in the eggs were increased. These results are important in determining the length of time needed to produce omega-3 enriched eggs following adding flaxseed in the diet of laying hens.

Relative to the data on levels of omega-6 fatty acids, our results showed that adding flaxseed to the laying hens did not significantly (p>0.05) affect the levels of omega-6 fatty acids in the egg yolk when compared with the control eggs. Our results are similar to that found by Caston and Leeson (1990). On the other hand, Bean and Leeson (2003) found that feeding flaxseed to laying hens for twenty weeks not only increased levels of omega-3 fatty acids but also decreased levels of omega-6 fatty acids in the egg yolk. The difference in the results could be due to the strain of birds that was used. As mentioned previously ratio between omega-6 to omega-3 fatty acids is important for the general human health. It was also mentioned that the lower the ratio the better it is for the human health in many aspects such as improving cardiovascular system, anti-inflammatory effects and reducing atherosclerosis. Our results show that the ratio between omega-6 and omega-3 fatty acids was significantly (p<0.05) decreased in the eggs of all groups fed flaxseed, four weeks following the treatment, relative to the control group. The ratio was further decreased at eight weeks following treatment reaching 2.33:1 in the eggs of the group that was fed 10% flaxseed. Our results agree with the results of Ferrier *et al*. (1995); Bean and Leeson (2003); Yannakopoulos *et al*. (2005); Ansari *et al*. (2006) and Yalcin and Unal (2010) who all found a decrease in the ratio of moega-6 to omega-3 fatty acids in eggs following adding flaxseed in the diet of laying hens. Our results and the results of others reinforce the importance of adding flaxseed in the diet of laying hens on producing eggs with lower ratio between omega-6 and omega-3 fatty acids than standard eggs. The ratio of 2.33:1 obtained from our results following feeding laying hens with 10% flaxseed is even lower than the 4:1 ratio recommended by WHO and FAO (1995) and the 5:1 reported by Kouba and Mourot (2011). The benefits of a lower ratio between omega-6 and omega-3 fatty acids have been indicated earlier. Some of these benefits include reducing the risk of many of the chronic diseases (Simopoulos, 2002; Harris *et al*., 2006), beneficial effects in patients with rheumatoid arthritis (James and Clelsnd, 1997), reduce proinflammatory cytokines (Cotogni *et al*., 2011), reduces atherosclerosis (Wan *et al*., 2010) and in general has an anti-inflammatory effect (Hagi *et al*., 2010). In addition, Simopoulos (2011) indicated that a lower ratio of omega-6 to omega-3 fatty acids is important for homeostasis and normal development throughout the life cycle.

Our results also indicated that the lower ratio that was obtained from feeding laying hens with 10% flaxseed is due to an increase in the levels of omega-3 fatty acids

Table 5: Overall averages throughout the experiment of different production parameters for control and treated hens

	Level of flaxseed in the diet			
Parameter	Control (0%)	5%	7.5%	10%
Percent egg production	91.9±4.9*	84.6±6.0	86.0±5.3	86.6±4.7
Egg weight (g)	56.8±4.3	56.3±2.7	55.9±3.7	56.3±4.3
Egg mass (g/bird/4 week period)	1445±181	1443±151	1431±168	1432±160
Feed efficiency	1.98±0.42	1.98±0.30	2.01±0.31	1.97±0.40

There were no significant differences (p>0.05) between the control and any of the different treatments for the different parameters that were measured. *Values are means±SD (n =15)

and not due to a decrease in the level of omega-6 fatty acids. Again our results indicate that our treatments not only increased levels of omega-3 fatty acids in the eggs of laying hens but also decreased the ratio of omega-6 to omega-3 fatty acids to the desired and recommended one and as such producing healthy and beneficiary poultry product.

Effects of treatments on different parameters of production performance: Data on effects of adding different levels of flaxseed in the diet of laying hens on overall averages for the entire experimental period, of the different production parameters that were measured are shown in Table 5. It is clear from our results that treating laying hens with different levels of flaxseed in their diets did not affect significantly (p>0.05) any of the production parameters measured including percent egg production, egg weight, egg mass, or feed efficiency. Our results agree with the findings of Yannakopoulos *et al.* (1999); Bean and Leeson (2003) and Yannakopoulos *et al.* (2005) who found that adding flaxseed to the diet of laying hens did not significantly affect egg production or egg weight and of Amini and Ruiz-Feria (2007) who found that adding flaxseed in the diet of laying hens did not significantly affect production performance. Ferrier *et al.* (1995) found no significant effect of adding flaxseed on egg weight and Novak and Scheideler (2001) found no significant effect of adding flaxseed on egg production. Furthermore, Grobas *et al.* (2001) found that adding linseed oil in the diet of laying hens did not significantly affect either egg production or egg weight. However, Scheideler and Froning (1996) and Scheideler *et al.* (1998) found that feeding flaxseed to laying hens improved egg production. Furthermore, Novak and Scheideler (2001) found that adding flaxseed in the diet of laying hens significantly increased egg weight.

Our results and the results of others indicate that adding flaxseed in the diet of laying hens could improve the production parameters but definitely does not adversely affect them. Therefore, it can be concluded from our results that adding 10% flaxseed in the diet of laying hens can result in producing omega-3 enriched eggs and reducing the omega-6: omega-3 ratio to the recommended one without any adverse effects on production performance. Hence, it is recommended to add flaxseed in the diet of laying hens in order to produce healthier poultry products.

ACKNOWLEDGEMENTS

This research was funded by Kuwait Institute for Scientific research.

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