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The effect of linseed oil supplementation of the diet on the content of fatty acids in the egg yolk

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Abstract

The aim of this study was to compare the effect of two different types of oils in diet on the fatty acid profile in the eggs of layers and to include a particular type of oil as a supplement of feeding mixtures for layers in order to support the development of functional foodstuffs. Thirty layers fed a diet containing soybean oil constituted the control group (soybean oil is the most frequently used oil added to feeding mixtures). In the experimental group (thirty layers), soybean oil was replaced with linseed oil at the same amount (3 kg of oil per 100 kg of feeding mixture). Feeding was provided *ad libitum* for all days of the month. After one month, egg yolks were analysed and the fatty acid profile was compared. Significant differences ($P \leq 0.05$) were found in the concentration of myristic acid that belongs to the group of saturated fatty acids. Eggs in the experimental group showed higher concentrations of myristic acid compared to the control group (0.20 g/100 g of fat and 0.18 g/100 g of fat, respectively). Highly significant differences ($P \leq 0.01$) were found for heptadecanoic acid but the trend was opposite to that of myristic acid; concentrations of heptadecanoic acid in the experimental group were lower than those in the control group. Highly significant differences ($P \leq 0.01$) 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 ($P \leq 0.01$) 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. The possibility of influencing the fatty acid profile in eggs is very important for the development of functional foods.

α-linolenic acid, layers, n-3, PUFA, MUFA

Lipids are an important component of feeds not only for their high content of energy but also for the content of essential fatty acids and fat-soluble vitamins. Oil plants and some legumes can serve as a source of oils to be used for supplementation of diets for poultry. Currently, flax (*Linum usitatissimum*) is a very intensively studied plant. Similar to other plant oils, linseed oil also contains linoleic acid, which is an essential fatty acid required by the body. It is also rich in α-linolenic acid that belongs to the group of n-3 fatty acids. The composition of fatty acids in egg depends on that of the feed, always reflecting the content of fatty acids that predominate in the respective oil plant (in oil) (Woods and Fearon 2009). Diet can affect the ratio of saturated and unsaturated fatty acids in the egg yolk (Milinsk et al. 2003). Diet supplemented with linseed oil particularly affects the concentrations of α-linolenic acid (Beynen 2004), oleic acid, n-3 fatty acids and docosahexaenoic acid (Celebi and Macit 2009). Linseed oil was found to increase the content of n-3 fatty acids (Jia et al. 2008). However, some studies have shown that linseed oil leads to an increase in the concentration of α-linolenic acid, which is associated with the decreasing content of docosahexaenoic and eicosapentaenoic acids (García-Rebollar et al. 2008). Due to flax oil supplementation of diet for layers, cholesterol in eggs decreases. As the concentration of n-3 fatty acids is elevated, eggs may be viewed as functional foodstuff (Suksombat et al. 2006). Gebauer et al. (2006) and Juturu (2008) reported that n-3

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polyunsaturated acids reduce the risk of developing cardiovascular diseases and cancer. The intake of these acids can help prevent breast cancer. These acids are also important for healthy development of the brain and immune system function (Lewis et al. 2000). The aim of this study was to compare the effect of two types of oils (linseed and soybean) in diet on the fatty acid profile in the egg yolk of layers. The results show that a particular type of oil could be included as supplement to feeding mixtures for layers in order to support the development of functional foodstuffs.

Material and Methods

A total of 60 Isa Brown hybrid combination layers were subjected to biological experiment. Feeding was ensured using a commercially produced, complete feeding mixture. Layers were reared using cage technology in an accredited experimental enclosure according to technological instructions for Isa Brown layers, at 16 h of light per day. Feed was provided *ad libitum*, watering was ensured using automatic feeders. Layers were divided into two groups. The diet in the control group was supplemented with commercially produced soybean oil; the feeding mixture in the experimental group was supplemented with linseed oil. The amount of oil added to the particular feeding mixture was the same in both groups (3 kg of oil per 100 kg of feeding mixture). The feeding mixture in the control group contained 169.3 g of crude protein, 61.2 g of fat, 27.0 g of fibre, 625.8 g of nitrogen-free extract substances, 34.1 g of calcium, 7.3 g of phosphorus, and 2.1 g of magnesium (in g per kg of dry matter). The feeding mixture of the experimental group contained 169.3 g of crude protein, 63.5 g of fat, 28.2 g of fibre, 619.5 g of nitrogen-free extract substances, 33.9 g of calcium, 7.2 g of phosphorus, and 2.3 g of magnesium (in g per kg of dry matter). The contents of fatty acids in control and experimental feeding mixtures are provided in Table 1. The eggs laid were analysed after the experiment. Eggs were collected daily and stored in the refrigerator. The collected eggs were broken every week. Egg yolks were separated from egg whites and yolks were subsequently frozen. Thirty eggs were used for the analysis of fatty acids. One sample for analysis consisted of three egg yolks. The egg yolk was analysed for fatty acids using gas chromatography with GC 2010 Shimadzu Gas Chromatograph. Samples for the determination of fatty acids were prepared using the method developed by Folche et al. (1957). The results were compared using the statistical programme Unistat CZ, for Excel version 5.6 (2005) at the level of significance being $P \leq 0.01$ (highly significant difference) and $P \leq 0.05$ (significant difference).

Table 1. Concentrations of fatty acids in diets of control (soybean oil) and experimental (linseed oil) groups of layers.

Fatty acid (g /100g fat)	Soybean oil	Linseed oil
lauric (c12:0)	0.01	0.00
myristic C14:0	0.08	0.04
palmitic C16:0	10.39	4.70
palmitoleic C16:1	0.08	0.06
heptadecanoic C17:0	0.13	0.07
cis-10-heptadecenoic C17:1	0.05	0.04
stearic C18:0	4.19	3.39
oleic/elaidic C18:1n9t+ C18:1n9c	22.10	18.82
linoleic/linolelaidic C18:2n6c + C18:2n6t	53.64	16.27
linolenic C18:3n3	8.17	56.26
arachidic C20:0	0.35	0.14
cis-11-eicosenoic C20:1n9	0.20	0.13
cis-11,14 eicosadienic C20:2n6	0.00	0.05
heneicosanic C21:0	0.04	0.09
arachidonic C20:4n6	0.00	0.09
cis -11,14,17-eicosatrienoic C20:3n3	0.00	0.04
behenic C22:0	0.42	0.12
tricosanoic C23:0	0.05	0.00
lignoceric C24:0	0.15	0.08

Results

Significant differences ($P \leq 0.05$) between the results of two groups of layers fed different diets were found for myristic acid, one of the saturated fatty acids (Table 2). After the administration of linseed oil, the concentration of myristic acid increased (0.18 g/100 g of fat and 0.20 g/100 g of fat for the control and experimental group, respectively). Highly significant differences ($P \leq 0.01$) were found for heptadecanoic acid but the trend was opposite to that of myristic acid. The egg yolk in the experimental group contained heptadecanoic acid at a concentration of 0.14 g/100 g of fat, whereas the

Table 2. Concentrations of saturated fatty acids and monounsaturated fatty acids (n-9) in yolk (× ± SD) in g per 100 g of fat from control and experimental groups of layers.

SFA	Control	Experimental
myristic C14:0	0.18 ± 0.02	0.20 ± 0.03*
palmitic C16:0	16.90 ± 2.08	17.12 ± 2.02
heptadecanoic C17:0	0.24 ± 0.03	0.14 ± 0.14**
stearic C18:0	5.64 ± 0.67	5.83 ± 0.84
arachidic C20:0	0.01 ± 0.005	0.01 ± 0.003
MUFA (n-9)		
myristoleic C14:1	0.03 ± 0.01	0.04 ± 0.01**
palmitoleic C16:1	1.65 ± 0.24	2.43 ± 0.37**
cis-10-hepta-decenoic C17:1	0.09 ± 0.01	0.09 ± 0.01
oleic/elaidic C18:1n9t+ C18:1n9c	25.35 ± 4.15	28.96 ± 3.76**
cis-11-eico-senoic C20:1n9	0.14 ± 0.02	0.11 ± 0.02**

control group - soybean oil in diet for layers (number of eggs-30)
experimental group - linseed oil in diet for layers (number of eggs-30)
SFA - saturated fatty acids
MUFA - monounsaturated fatty acids
*$P \leq 0.05$
**$P \leq 0.01$

Table 3. Concentrations of polyunsaturated fatty acids (n-6) and (n-3) in yolk (× ± SD) in g per 100g of fat in g per 100 g of fat from control and experimental groups of layers.

PUFA (n-6)	Control	Experimental
linoleic C18:2n6c + C18:2n6t	15.91 ± 2.12	13.22 ± 1.80**
γ-linolenic C18:3n6	0.09 ± 0.01	0.06 ± 0.01**
cis-11,14-eicosadienoic C20:2n6	0.14 ± 0.02	0.08 ± 0.02**
cis-8,11,14-eicosatrienoic C20:3n6	0.09 ± 0.01	0.08 ± 0.01
arachidonic C20:4n6	1.50 ± 0.17	0.88 ± 0.18**
docosatetraenoic C22:4n6	0.10 ± 0.02	0.03 ± 0.01**
PUFA (n-3)		
α-linolenic C18:3n3	0.82 ± 0.11	5.63 ± 0.92**
cis-11,14,17-eicosatrienoic C20:3n3	0.02 ± 0.004	0.09 ± 0.02**
cis-5,8,11,14,17-eicosapentaenoic C20:5n3	0.02 ± 0.01	0.13 ± 0.02**
cis-4,7,10,13,16,19-docosahexaenoic C22:6n3	1,09 ± 0,13	1,63 ± 0,25**
docosapentaenoic C22:5n3	0.10 ± 0.02	0.28 ± 0.05

control group - soybean oil in diet for layers (number of eggs-30)
experimental group - linseed oil in diet for layers (number of eggs-30)
PUFA - polyunsaturated fatty acids
*$P \leq 0.05$
**$P \leq 0.01$

egg yolk in the control group contained heptadecanoic acid at a concentration of 0.24 g/100 g of fat. Highly significant differences ($P \leq 0.01$) were observed in monounsaturated fatty acids (n-9 MUFA), except for cis-10-heptadecanoic acid where the differences between the groups were non-significant (Table 2). The concentration of cis-11-eicosenoic acid in the experimental group was lower ($P \leq 0.01$) compared to the concentration of cis-11-eicosenoic acid in the egg yolk (0.14 g/100 g of fat and 0.11 g/100 g of fat in the control and experimental group of layers, respectively). The concentrations of other fatty acids in the experimental group (Table 2) increased after administration of diet supplemented with linseed oil. Linseed oil affected the concentration s of n-6 fatty acids (Table 3). After its administration, the concentrations of n-6 fatty acids dropped ($P \leq 0.01$) below those in the control group. In contrast, linseed oil had a very positive effect on n-3 fatty acids (Table 3), particularly on α-linolenic acid whose concentration in experimental yolks was 5.63 g/100 g compared to 0.82 g/100 g of fat in the control group. Other fatty acids also showed increased concentrations in the experimental group at the level of significance $P \leq 0.01$.

Discussion

Functional foodstuffs have recently attracted great attention, including eggs with modified concentrations of fatty acids. The fatty acid profile of egg can be affected by feed as documented in our experiment. Similar findings were also reported by Milinsk et al. (2003), Woods and Fearon (2009). Supplementation of diet for utility layers with linseed oil can be recommended. Linseed oil has a profound effect on the concentrations of α-linolenic acid and other fatty acids in this group of acids. Our results are in a good agreement with those reported by Beynen (2004), Jia et al. (2008), and Celebi and Macit (2009) who also reported elevated concentrations of α-linolenic acid after the administration of linseed oil. Some studies (García-Rebollar et al. 2008) showed that the increasing concentration of α-linolenic acid is associated with decreasing concentrations of docosahexaenoic and eicosapentaenoic acids. However, our results indicate that concentrations of docosahexaenoic and eicosapentaenoic acids in the experimental group (1.63 g/100 g of fat and 0.13 g/100g of fat, respectively) were higher than those in the control group (1.09 g/100 g of fat and 0.02 g/100 g of fat, respectively); differences were highly significant ($P \leq 0.01$). The increased intake of n-3 fatty acids reduces the incidence rate of cardiovascular diseases, decreases the concentration of triglycerides in blood, lowers blood pressure, and can prevent arrhythmias. Our study revealed an increase in the concentrations of n-3 fatty acids in eggs from layers fed a diet supplemented with linseed. Eggs produced by layers feeding on enriched diet can therefore be included among functional foodstuffs.

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