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Modification of polyunsaturated fatty acid contents in yolk lipids using various cereals and blended animal fat in hens' diets

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ABSTRACT

Ten groups of 36 Tetra SL hens were caged individually. They were fed 10 diets containing 17% crude protein and 11.6 MJ ME/kg, in which the cereals were: wheat or maize only, or the following cereal mixes (1:1): wheat and maize; barley and naked oats, or barley; regular or naked oats in combination with wheat or maize. The chemical composition of cereals, the fatty acid profiles in grain cereals, blended fat, and of the yolks of 12 eggs from each group were determined. The content of n-6 and n-3 fatty acids and their ratio in egg-yolk lipids varied widely according to the type of cereal and level of animal fat in the diet. Diets containing barley with naked oats or wheat, and maize with regular oats, supplemented with adequate amounts of blended animal fat are considered favourable in terms of increasing the level of n-3 fatty acids and decreasing the PUFA n-6/n-3 ratio in egg yolks.

KEY WORDS: yolk lipids, cereals, laying hen

INTRODUCTION

Enriching human food with polyunsaturated fatty acids (PUFA) n-3 has beneficial effects on health. These include decreased risk of heart disease and stroke and advantageous immunological and neurological effects (Whitehead, 1999). For human nutrition, the highest recommended uptake level of n-6:n-3 is 10:1. However, the normal human diet contains about 30 times more n-6 fatty acids than n-3 fatty acids (Barlow and Pike, 1991). Enriching eggs with n-3 fatty acids can be done by using different dietary fat sources. Among the richest sources of n-3 fatty acids are fish oils and linseed, but they give off-flavours in eggs and lead to problems with oxidative stability. Marine algae are another rich source of n-3 PUFA (Whitehead, 1999).

The presence of fatty acids in cereal grains has been generally disregarded. Their content of PUFA, especially n-3, is relatively low, but cereals form about 70% of hens' diets. In some countries it is not possible to substitute some cereals with others. In the United States, maize is almost the only cereal used in feeds for hens. In Poland and in our climatic zone, however, it is possible to use various cereals in hen nutrition depending on market supply, price and tradition of use.

The aim of the experiment was to determine the extent to which cereals with varying PUFAs and fat contents can affect fatty acid profiles in egg yolk.

MATERIAL AND METHODS

Three-hundred and sixty Tetra SL laying hens were assigned to 10 groups in 2 replications of 18 hens and kept individually in cages. They were fed ten isoenergetic (11.6 MJ ME/kg) and isoprotein (17% CP) diets that contained ground cereals: wheat (group 1) or maize (group 10), or the following cereals at a 1:1 ratio: wheat and maize (group 2), wheat and barley (group 3), wheat and regular oats (group 4), wheat and naked oats (group 5), maize and barley (group 6), maize and regular oats (group 7), maize and naked oats (group 8), barley and naked oats (group 9). The level of metabolizable energy in the diets was balanced with blended animal fat. The level of crude protein was balanced by different the amounts of soyabean meal. Each diet contained 3.5% meat-and-bone meal. The cultivars used were: Rodos (barley), Elena (wheat), and Akt (naked oats), produced in the Cracow region, and regular oats and maize.

Egg production was recorded daily, all eggs were weighed for 5 successive days per month.

Analysis of fatty acids in yolks of 12 eggs from each group and in ground cereals was performed using a GC VARIAN 3400 gas chromatograph equipped with DB-FFAP 1.0, 30 m and 0.53 mm columns. Dry matter (DM) and nutrient content of cereals and experimental diets was determined according to AOAC (1990) methods.

The results were subjected to one-factorial ANOVA GLM analysis, SAS Institute (1985) for all groups and to a two-factorial design: type of cereal (barley, regular oats or naked oats) x maize or wheat for 6 groups.

RESULTS

The naked oats grain contained 65% more fat in DM than maize (Table 1), but less C18:2 PUFA than maize (42 vs 63%). Maize lipids contained the least saturated fatty acids (SFA), which were the highest in the fat of barley and naked oats.

TABLE 1

Ether extract in DM and fatty acids content in blended animal fat and cereals, % of total fatty acids

Fatty acid	BF	Barley	Maize	Naked oats	Regular oats	Wheat
Ether extract	95.10	1.74	4.07	6.74	3.67	2.19
C 18:2	4.15	57.68	63.01	42.14	48.83	66.56
C 18:3	0.33	4.72	1.20	1.16	1.33	4.28
SFA	47.80	22.80	11.42	22.73	19.72	15.87
MUFA	43.91	14.79	24.37	33.96	30.12	13.29
PUFA n-6 / n-3	12.57	12.22	52.31	36.23	36.59	15.55

The PUFA content was the highest in wheat and the lowest in naked oats. The highest content of n-3 fatty acids and the lowest (most beneficial) PUFA n6/n3 ratio was characteristic of Rodos barley and Elena wheat fat. The poorest PUFA n-6/n-3 ratio was found in maize fat.

Due to the low content of fat in diets containing some cereals, the metabolizable energy level in feed was adjusted by adding blended animal fat from processing plants; this fat contained over twice as much SFA than did cereals. The largest supplementation was required by diets with barley and regular oats, to which 2.1-5.7% BF was added (Table 2).

There were no significant differences among the groups of hens in laying rate, which averaged 88% during a period of 9 months. Hens that received maize and barley (M+B), maize and oats (M+RO, M+NO), wheat and naked oats (W+NO)

TABLE 2

Amounts of C 18:2 and C 18:3 FA incorporated into diets from cereals and BF, mg/kg DM

Diet	1	2	3	4	5	6	7	8	9	10
Cereals	W	W+M	W+B	W+RO	W+NO	M+B	M+RO	M+NO	B+NO	M
C 18:2	992	1 360	805	1 046	1 579	1 560	1 390	1 935	1 361	1 705
C 18:3	64	33	57	46	63	43	31	45	57	32
BF, %	2.5	1.4	4.3	5.7	0.4	3.1	4.6	0.2	2.1	0.6
C 18:2	975	550	1680	2222	156	1209	1794	78	819	234
C 18:3	77	43	133	178	13	96	133	6	65	19
Σ C 18:2	1967	1910	2485	3268	1735	2769	3184	2013	2180	1939
Σ C 18:3	141	76	190	224	76	139	164	51	122	51
C18:2/18:3	13.9	25.6	13.1	14.6	22.8	19.9	19.4	39.5	17.8	38.0

B – barley, M – maize, NO – naked oats, RO – regular oats, W – wheat, BF – blended animal fat

supplemented with 3.1, 4.6, 0.2 and 0.4% BF, respectively, laid heavier eggs (65 g) than hens fed only wheat or maize, or wheat in combination with other cereals (63.8 g).

The highest levels of n-3 fatty acids (Table 3) were found in yolk from hens fed barley and naked oats (B+NO), barley and wheat (W+B), maize and regular oats (M+RO). However, this level was not significantly different from that found in the eggs laid by hens fed diets in which the content of PUFA n-3 from cereals and BF was higher or equal to 140 mg/kg (Table 2). Hens fed diets in which PUFA n-3 from cereals and BF was as low as 51-76 mg/kg laid eggs in which amount of PUFA n-3 was the lowest.

TABLE 3

Fatty acids composition in yolk lipids, % of total fatty acids

Group	1	2	3	4	5	6	7	8	9	10
SFA	34.36	34.13	33.85	33.93	33.83	34.00	34.00	34.91	33.78	34.81
MUFA	52.22^{A}	50.69	52.68^{A}	51.70	50.66	50.45	49.73	48.91^{B}	50.58	49.77*
PUFA	13.43^{B}	15.18	13.47	14.40	15.56	15.55	16.26^{A}	16.27^{A}	15.50	15.48*
PUFA n-6	12.46^{BC}	14.32	12.37^{C}	13.46	14.86	14.63	15.18^{AB}	15.53^{A}	14.39	14.74**
PUFA n-3	0.97^{AB}	0.85^{BC}	1.10^{A}	0.95^{ABC}	0.74^{C}	0.91^{ABC}	1.09^{A}	0.73^{C}	1.11^{A}	0.73^{C}
PUFA n-6/n-3	13.17^{CD}	17.46^{ABC}	11.52^{D}	15.45^{CD}	20.47^{AB}	16.36^{CD}	13.99^{CD}	21.13^{A}	13.70^{CD}	20.85^{AB}

* other groups in the row bear superscript AB, ** other groups in the row bear superscript ABC, means bearing the same superscript A, B, C, do not differ significantly ($P<0.01$)

The most beneficial (lowest) PUFA n-6/n-3 ratio (11.5-15.5) was in the lipids of egg yolks from hens given diets containing W+B, W, B+NO or regular oats in combination with maize or wheat, supplemented with 4.3, 2.5, 2.1, 4.6 or 5.7% BF, respectively. The highest PUFA n-6/n-3 ratio (20.5-21.1) was found in yolk from hens fed M+NO, M, and W+NO, i.e. in the diets in which PUFA n-6/n-3 from cereals and BF was 23-39 (Table 2).

DISCUSSION

There were no significant differences among the groups for SFA content. This is in agreement with Hargis and Elswyk (1993) who reported that even a high level of SFA in the diet has little influence on the level of these fatty acids in yolk. The present experiment also confirmed the observation of Naber (1979) that changes in the content of linoleic and linolenic acids are accomplished by substitution for oleic acid (C18:1).

The lipids of eggs laid by ISA Brown layers fed a diet containing 40% maize and 1% blended animal fat (Kamińska, 1999) also had a lower ($P<0.01$) PUFA

n-3 level and higher PUFA n-6/n-3 ratio than yolks from hens fed the diet containing barley and wheat (1:1) supplemented with 4.7% BF. However, in the experiment on 380 Babcock layers (Kamińska et al., 2000), the highest levels of PUFA n-3 were found not only in the yolks from hens fed the diet containing barley and dehulled oats (1:1) with 3.3% BF, but also in eggs from layers offered the diet containing 50% dehulled oats and 24% wheat supplemented with 0.5% BF. In an experiment by Sirri et al. (1995), the content of n-3 fatty acids in egg yolks from hens given 3% dietary maize oil was as low as with 3% supplementation with beef tallow.

Both barley and regular oats can yield very good results in layer nutrition when the diet is supplemented with an adequate amount of fat to balance the metabolizable energy level. It was found that even fat from animal processing plants can give good results.

CONCLUSIONS

The content of n-3 and n-6 fatty acids in egg yolk lipids can vary widely according to the type of cereal and level of blended animal fat in the diet. Barley combined with naked oats or wheat, and maize combined with regular oats are considered very favourable in terms of increasing the level of n-3 fatty acids and decreasing PUFA n-6/n-3 ratio in egg yolks.

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STRESZCZENIE

Modyfikacja zawartości wielonienasyconych kwasów tłuszczowych w lipidach żółtka jaj poprzez zastosowanie różnych zbóż w mieszankach paszowych dla kur

Doświadczenie przeprowadzono na 10 grupach kur Tetra SL po 36 w grupie, trzymanych pojedynczo w klatkach. Nioski żywiono 10 mieszankami zawierającymi 17% białka ogólnego i 11,6 MJ ME/kg, z udziałem następujących zbóż: wyłącznie pszenica lub kukurydza, lub w stosunku 1:1 w kombinacjach: pszenica z kukurydzą; jęczmień, owies normalny lub nagi z pszenicą lub kukurydzą; jęczmień z owsem nagim. Oznaczono skład chemiczny zbóż oraz zawartość kwasów tłuszczowych w ziarnie zbóż i w żółtkach 12 jaj z każdej grupy. Zawartość kwasów tłuszczowych z rodziny n-6 i n-3 oraz stosunek PUFA n-6/n-3 w lipidach żółtek jaj różnił się znacznie w zależności od rodzaju zboża oraz poziomu tłuszczu utylizacyjnego dodanego do mieszanki paszowej. Najlepsze wyniki dotyczące zwiększenia ilości kwasów tłuszczowych n-3 i obniżenia stosunku PUFA n-6/n-3 w żółtkach jaj uzyskano żywiąc kury mieszankami zawierającymi jęczmień i owies nagi lub pszenicę, bądź kukurydzę i owies z łuską.