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ANIMAL PRODUCTION

The Effect of Oat Fractions and Strain of Laying Bird on Production and on the Cholesterol and Fatty Acid Content of Eggs

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Abstract. The effects of feeding various fractions of oats (whole oats, dehulled oats and oat hulls) in a wheat diet on the production, yolk cholesterol and yolk fatty acid concentrations of three strains of laying birds were studied for 12 weeks. There was no significant difference between birds fed the different oat fractions in weight gain, egg production, egg weight, daily cholesterol output or yolk concentration of palmitic, stearic or oleic acids or yolk unsaturated:saturated fatty acid ratio.Birds fed whole oat grain (WO) had lower yolk cholesterol concentration and content than those fed the wheat diet. Birds fed the dehulled oats (DO) diet significantly increased their yolk weight and yolk oleic to linoleic acid ratio when compared with those fed the WO. When oat hulls (OH) were substituted for some of the DO, birds significantly increased their yolk color and caused a nonsignificant reduction in their production parameters so that they were not significantly different from birds fed the WO diet. The addition of OH to a wheat based diet significantly increased feed consumption. There were differences among strains of birds in weight gain, feed consumption, rate of lay, egg weight, yolk weight, yolk color, and yolk cholesterol but not in egg mass, yolk fatty acid concentrations or daily cholesterol output. It was concluded that WO did not significantly alter egg production parameters or daily yolk cholesterol output but did significantly decrease yolk cholesterol concentration. Two strains of layers produced eggs with lower yolk cholesterol than the third strain.

Introduction

Whole oat grains (WO) have been used as the only grain in laying hen diets without affecting egg production [1]. Dietary oats in layer diets have been shown to reduce yolk cholesterol concentration [2, 3]. Oat hulls (OH), dehulled oats (DO), oat starch, oat oil and oat gum have been extracted from WO, however the contribution of each of these fractions in the lowering effects of yolk cholesterol has not been determined. The addition of 15% OH to wheat based diets reduced yolk cholesterol, feed efficiency and egg size [4]. Various components of oats have been found to have cholesterol-lowering effects in chicks. Fisher and Griminger [5] reported that OH was better than either WO, or DO in lowering blood cholesterol of chicks fed hypercholesterolemic diets. Oats starch and oat oil in hypercholesterolemic diets had no cholesterol-lowering effect. Chenoweth and Bennink [6] reported that WO and defatted oats had cholesterol-lowering effects, whereas defatted-defibered oats and defatted-defibered-degummed oats had no cholesterol-lowering effects. Qureshi *et al.* [7] confirmed that WO had cholesterol-lowering effects in chicken.

This experiment examined the effects of DO and OH on egg production and yolk cholesterol of three commercial strains.

Materials and Methods

Three commercial strains of 38-week old birds were used and started on the experimental diets. A total of 180 from each strain of birds were used. Birds from the same strain were housed in a block of six cages with two birds per cage. Each block was treated as an experimental unit. Egg production and feed intake were recorded for the entire group as a replicate. Feed and water were available ad libitum. Diets were supplied as mash. A photoperiod of 14 h commenced when the birds were caged at 22 weeks of age and was maintained throughout the trial.

The experiment was a 3 x 5 factorial, the variables being strain of bird and oat fractions. The oat fractions tested were DO, OH, DO plus OH and WO. The WO and oat fractions substituted half the wheat in a 75% wheat basal diet. Each experimental diet was fed to three replicates. The composition of the basal diets is shown in Table 1.

The experiment lasted 12 weeks. Calculations were based on a 4-week period for feed consumption and egg weight (based on the weight of a complete egg collection for one day each week). Yolk color was based on a sample of 5 eggs from each replicate for one day each week and calculations were based on 4-week periods. Egg cholesterol and fatty acids were determined every 2 weeks starting from the third week of the experiment. Two eggs were randomly sampled from each replicate, weighed and then the yolk was separated, weighed, homogenised and placed in an airtight container prior to analysis. Cholesterol mass was calculated using the egg production data starting from the third week of the experiment parallel to cholesterol analysis.

Table 1. The composition of the basal diets (g/kg)

	Basal diet				
	1	2	3	4	5
Ingredient					
Wheat	753.6	376.8	675.9	376.8	376.8
Oats	-	-	-	-	376.8
Dehulled oats	-	376.8	-	299.1	-
Oat hulls	-	-	77.7	77.7	-
Meatmeal (53% protein)	100	100	100	100	100
Cottonseed meal	40	40	40	40	40
Soybean meal	30	30	30	30	30
Limestone	70	70	70	70	70
Salt	2	2	2	2	2
L-lysine hydrochloride	1.7	1.7	1.7	1.7	1.7
DL-Methionine	0.7	0.7	0.7	0.7	0.7
*Vitamin/mineral premix	2	3	2	2	2
Analysis					
Crude protein (g/kg, N x 6.25)	177	184	171	181	173
Calculated metabolizable energy (MJ/kg)	11.5	11.4	10.7	10.6	10.7
Fibre%	3.2	3.5	5.0	5.3	6.2

***The composition of vitamins and minerals in the premix :**
Retinol, 4.8 mg; cholecalciferol, 1.6 mg; riboflavin, 0.8 mg; menadione sodium bisulphite, 0.2 mg; manganese sulfate, 16 mg; ethoxyquin, 44.8 mg; zinc bacitracin, 4 mg; zinc oxide, 6 mg; apocarotenoic ester (%10), 9.75 mg; canthaxanthin (%10), 3.75 mg; carrier (pollard) made up to 2 g.

Yolk color score was measured by using a Roche Color fan (Roche Chemicals Pty Ltd). was extracted by the method of Folch *et al.* [8] and fatty acid concentrations were determined by gas-liquid chromatography [9]. Cholesterol was determined by the method of Ishikawa *et al.* [10]. Data collected were subjected to analysis of variance [11]. When significant variance ratios were detected, differences between treatment means were tested using the least significant difference procedure.

Results

There was no significant difference among diets in bird weight gain, rate of lay, egg weight or daily cholesterol output (Tables 2 and 3). Birds fed the WO or OH diets consumed significantly ($P < 0.05$) more feed than those fed the W basal diet. Birds fed the WO significantly ($P < 0.05$) produced lower egg mass than those fed DO diets. There was no significant difference between birds fed the W, DO or DO plus OH in feed consumption or egg mass. Eggs from birds fed the W, DO or OH diets had significantly ($P < 0.01$) lighter yolk color than those produced by birds fed WO or DO plus OH (Table 3). There was no significant difference between the yolk colors of eggs produced from feeding the WO or the DO plus OH based diets. Eggs from birds fed the DO diet had significantly ($P < 0.05$) heavier yolks than those produced by birds fed any of the other diets. Eggs from birds fed the WO diet had a significantly lower yolk cholesterol concentration than those from birds fed the W diet. Yolk cholesterol content was significantly (P <0.01) lower in eggs from the WO treatment than in eggs produced by birds fed the DO or W diets. The inclusion of OH or OH plus DO, in the diets did not significantly decrease yolk cholesterol concentration or content.

Table 2. Effects of oat fractions and strain of bird on the performance of laying hens

	Weight gain (g)	Feed consumption (g)	Rate of lay (egg/hen/day)	Egg weight (g)	Egg mass (g)
Type of grain [1]					
W	130.0	110.7 [b]	0.83	56.2	46.6 [ab]
W + DO	128.3	113.6 [ab]	0.84	57.1	48.0 [a]
W + OH	109.6	119.1 [a]	0.82	56.2	46.1 [ab]
W + DO + OH	121.0	114.8 [ab]	0.83	55.8	46.3 [ab]
W + WO	101.1	118.1 [a]	0.81	55.9	45.3 [b]
LSD[2] (P < 0.05)	58.5	6.8	0.04	1.7	2.6
Strain					
1	134.7 [a]	114.3 [b]	0.85 [a]	54.1 [b]	46.1
2	82.2 [b]	109.4 [b]	0.81 [b]	57.8 [a]	46.7
3	137.4 [a]	119.7 [a]	0.82 [b]	56.8 [a]	46.6
LSD[2] (P < 0.05)	41.5	4.7	0.03	1.2	1.8

[1] W= Wheat, DO=Dehulled oats, OH=Oat hulls, WO=Whole oats.

[2] Least significant differences (P < 0.05) with 112 degrees of freedom for all measurements except for body weight gain which had 58 degrees of freedom.

[ab] Treatment means within columns followed by different letters are significantly different (P < 0.05).

Table 3. Effects of oats and strain of bird on yolk color, yolk weight and yolk cholesterol content

Treatment	Yolk color score[3]	Yolk weight (g)	Cholesterol concentration (mg/g yolk)	Cholesterol content (mg/yolk)	Cholesterol output[4] (mg/day)
Type of grain [1]					
W	13.3 [b]	17.6 [b]	12.0 [a]	211.4 [a]	175.3
W + DO	13.3 [b]	18.4 [a]	11.5 [ab]	211.6 [a]	177.7
W + OH	13.4 [b]	17.7 [b]	11.6 [ab]	205.3 [ab]	168.3
W + DO + OH	13.8 [a]	17.4 [b]	11.8 [ab]	205.7 [ab]	170.7
W + WO	13.7 [a]	17.2 [b]	11.4 [b]	196.1 [b]	158.8
LSD[2] (P < 0.05)	0.2	0.6	0.6	15.0	23.1
Strain					
1	13.5 [b]	17.2 [b]	11.4 [b]	196.0 [b]	166.5
2	13.5 [b]	18.1 [a]	11.2 [b]	203.9 [b]	165.6
3	13.7 [a]	17.8 [a]	12.2 [a]	217.2 [a]	178.1
LSD[2] (P < 0.05)	0.1	0.4	0.4	10.1	15.3

[3] Yolk color score was measured by using a Roche color fan.

[4] Cholesterol daily output was calculated using the egg production data starting from the third week of the experiment parallel to yolk cholesterol sampling procedure as described in the materials and methods.

[ab] Treatment means within columns followed by different letters are significantly different (P < 0.05).

Eggs from birds fed the DO diet had a significantly ($P < 0.05$) higher yolk oleic to linoleic acid ratio than those fed the WO diet (Table 4). There was no significant difference in yolk oleic to linoleic acid ratio between eggs produced from birds fed wheat, OH or DO plus OH treatments. Dietary treatment did not significantly alter yolk unsaturated (oleic plus linoleic) to saturated (palmitic plus stearic) fatty acid ratio, nor the concentrations of palmitic, stearic, oleic and linoleic acids in the yolk. Significant negative correlations were found between rate of lay and egg weight ($r = -0.66$, $P < 0.01$) and yolk weight ($r = -0.41$, $P < 0.01$) and significant positive correlations found between yolk cholesterol concentration and egg weight ($r = 0.31$, $P < 0.05$).

Table 4. Effects of oats and strain of bird on yolk fatty acid concentration

Treatment	Fatty acids				Uns/sat ratio[1]	18:1/18:2 ratio[2]
	16:0	18:0	18:1	18:2		
	(% of total methyl esters of yolk lipid)					
Type of grain						
W	22.93	9.06	36.11	11.56	0.67	3.16[ab]
W + DO	23.80	9.44	38.04	11.60	0.67	3.29[a]
W + OH	23.01	8.67	36.93	11.98	0.65	3.10[ab]
W + DO + OH	23.72	8.78	37.52	11.87	0.66	3.20[ab]
WO	22.71	9.13	36.56	12.17	0.65	3.01[b]
LSD[3] ($P < 0.05$)	1.80	0.89	2.59	0.69	0.05	0.23
Strain						
1	23.31	9.12	37.16	11.88	0.66	3.16
2	22.91	8.99	37.76	12.10	0.64	3.14
3	23.68	9.00	36.97	12.21	0.67	3.05
LSD[3] ($P < 0.05$)	1.25	0.62	1.80	0.48	0.04	0.16

[1] The proportion of unsaturated [oleic (18:1) and linoleic (18:2)] to saturated [palmitic (16:0) and stearic (18:0)] fatty acid in yolk lipid.
[2] The proportion of monounsaturated (oleic) to polyunsaturated (linoleic) fatty acid in yolk lipid.
[3] Least significant differences ($P < 0.05$) with 46 degrees of freedom.
[ab] Treatment means within columns followed by different letters are significantly different at $P < 0.05$.

The strains of birds responded differently to the diets (Tables 2,3 and 4). Strain 2 had a significantly ($P < 0.05$) lower body weight gain than the other strains. Strain 1 had a significantly ($P < 0.01$) greater rate of lay than other strains. Feed consumed by strain 3 was significantly ($P < 0.01$) greater than that of other strains. There was no significant difference between strains of birds in egg mass. Strain 1 had significantly ($P < 0.01$) lighter eggs and yolk weight than the other strains. There was no significant difference between strains 2 and 3 in rate of lay, egg weight or yolk weight, but yolk color produced by strain 3 was significantly ($P < 0.05$) darker than that produced by either strain 1 or 2. Egg yolk cholesterol concentration and yolk cholesterol content produced by strain 3 were significantly ($P < 0.05$ and $P < 0.01$, respectively) higher than those produced by strain 1. There was no significant difference between strains 1 and 2 in yolk cholesterol concentration or content. Strain of bird did not significantly affect daily cholesterol output or yolk fatty acid concentrations.

Discussion

Egg production, egg weight and egg mass were not significantly affected by the substitution of half the wheat in a 75% wheat diet with oat or oat components. This is in agreement with the findings of Duncan *et al.* [1]. While dehulled oats increased the size of egg yolk, they did not affect the size of the egg. The ratio of yolk weight to egg weight was therefore greater in eggs produced by birds fed the DO than those fed other diets. The increase in feed consumption of birds fed the OH and WO diets may have been due to the lower metabolizable energy and higher fiber contents.

There was some variation among the WO and oat fractions in their ability to reduce yolk cholesterol. The addition of WO grains reduced yolk cholesterol concentration and content, whilst the addition of oat fractions decreased yolk cholesterol below that produced by the wheat basal diet. It appears that a cholesterol lowering fraction may be eliminated during the dehulling process as neither the DO, OH nor DO plus OH were as effective in lowering yolk cholesterol as WO. The fraction of oats that causes cholesterol reduction in eggs was not identified in this trial. Despite the effects of oat fractions on yolk cholesterol concentration and content, there was no significant change in daily yolk cholesterol output. The effect of oats on yolk cholesterol may be related to the amount of fiber present in the grain. Kritchevsky and Story [12] reviewed the mechanisms by which dietary fiber may influence cholesterol metabolism. These include possible interactions between dietary fiber and bile salts with a consequent increase in cholesterol excretion.

Genetic variations among strains of birds in egg yolk cholesterol content were related to differences in the proportion of egg yolk and egg production [13,14]. Within strains, the fluctuation in egg yolk cholesterol was related to changes in egg weight, yolk weight and egg production rather than cholesterol output. Yolk cholesterol is controlled both by the amount of daily cholesterol produced and the egg production rate. Our results show that egg yolk cholesterol and the proportion of egg yolk appear to have separate genetic controls. The difference in yolk cholesterol content between the strains 2 and 3 was not due to a difference in yolk weight but mainly to a difference in yolk cholesterol concentration. The difference in yolk cholesterol content between strains 1 and 3 was due to a combination of differences in the yolk weights and yolk cholesterol concentrations. Previous reports of a relationship between yolk weight and yolk cholesterol are not consistent. Nichols *et al.* [15] reported an inverse relationship between yolk weight and yolk cholesterol content; Turk and Barnett [4] reported that yolk cholesterol content increased with egg size; and Menge *et al.* [16] found no correlation between yolk weight and yolk cholesterol content. The inconsistent relationship reported between yolk weight and yolk cholesterol content in different strains is probably due to the independence of inheritance of these two characters.

The relationship between yolk cholesterol and egg production was in agreement with Washburn and Marks [17] who found that variation in yolk cholesterol content was associated with a variation in egg production between low and high cholesterol lines. However, when the average daily egg cholesterol was calculated, the negative correlation resulted in no change in daily cholesterol mass between the low and high cholestrol lines. In contrast, Harris and Wilcox [18] reported no correlation between yolk cholesterol and egg production in different strains. The finding that average daily cholesterol output is not affected by strain of birds suggests that strain of bird may have an indirect effect on egg cholesterol concentration and content. This conclusion helps to explain the variability in previously reported results. Lower yolk cholesterol was associated with lower egg and yolk weights and higher rate of lay in strain 1 birds. Higher yolk cholesterol was associated with higher egg and yolk weights and lower rate of lay in strain 3 birds. Based on these results selection of birds for higher egg weight may be expected to increase yolk cholesterol content while selection for higher egg production may be expected to decrease yolk cholesterol content.

It was concluded that whole oats reduced yolk cholesterol apparently through the effect of decreased yolk cholesterol concentration. The oat fraction causing the lower cholesterol concentration was not identified as the inclusion of DO and OH, separately or together, did not produce yolk cholesterol concentrations as low as did WO. However several of the oat fractions decreased yolk cholesterol below that produced by the wheat based diet. Two strains of layers produced eggs with lower yolk cholesterol than a third strain.

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تأثير حبة الشوفان وسلالة الدجاجة البياضة على الإنتاج وعلى الكوليسترول والأحماض الدهنية للبيضة

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(قدم هذا البحث للنشر في ١٤١٨/١٠/١٠هـ ؛ وقبل للنشر في ١٤١٩/٢/٧هـ)

ملخص البحث. أجريت تجربة لدراسة تأثير التغذية على الشوفان (حبة كاملة - حبة مقشورة - قشور حبة الشوفان) في عليقة من القمح على الأداء وعلى الكوليسترول والأحماض الدهنية للبيضة، وذلك لثلاث سلالات من الدجاج البياض لمدة ١٢ أسبوعا. وقد أظهرت الدراسة أنه لا يوجد أي اختلافات معنوية بين الطيور التي غذيت على علائق مختلفة تحتوي على أجزاء من حبة الشوفان في وزن الجسم وإنتاج البيض ووزن البيضة وإنتاج الكوليسترول اليومي وتركيز حامض البالمتيك والاستياريك والأولييك ونسبة الأحماض الدهنية غير المشبعة إلى الأحماض الدهنية المشبعة في الصفار. بينما أدت إضافة حبة الشوفان كاملة إلى تقليل تركيز الكوليسترول في الصفار عند مقارنتها بعليقة القمح الأساسية. بينما أدت إضافة حبة الشوفان المقشورة إلى زيادة حجم صفار البيضة وزيادة تركيز نسبة حامض الأولييك إلى حامض اللينوليك في الصفار عند مقارنته بالعليقة المحتوية على حبة الشوفان الكاملة. وأدى إحلال جزء من الشوفان المقشور في العليقة بقشور حبة الشوفان إلى زيادة تركيز لون صفار البيض، ولم تؤثر على الصفات الإنتاجية الأخرى. بينما أدت إضافة قشور الشوفان إلى عليقة القمح الأساسية إلى زيادة استهلاك كمية الغذاء.

ولقد أظهرت الدراسة اختلافات بين سلالات الدجاج في زيادة وزن الجسم والغذاء المستهلك، وإنتاج البيض، ووزن البيضة، ووزن الصفار، ولون الصفار، وتركيز الكوليسترول في الصفار، ولم تظهر أية اختلافات بين سلالات الدجاج في كل من إنتاج البيض اليومي وتركيز الأحماض الدهنية في الصفار وإنتاج الكوليسترول اليومي.

ويتضح من هذه التجربة أن إضافة حبة الشوفان الكاملة إلى عليقة الدجاج البياض أدت إلى انخفاض تركيز الكوليسترول في صفار البيضة بدون إحداث أي تأثير معنوي على مقاييس إنتاج البيض أو إنتاج الكوليسترول اليومي للدجاجة ، وأن هناك اختلافات وراثية بين السلالات المنتجة للبيض ، إذ أنتجت سلالتان من الدجاج بيضا أقل تركيزا للكوليسترول عن السلالة الثالثة.