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Investigation of the Effects of Oat and Barley Feeding on Performance and Some Lipid Parameters in Table Ducks

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ABSTRACT : The effects of barley and oat feeding in table duck were investigated. During a 49-day growing period a corn-based diet was supplemented by 45% barley and 45% oats (isonitrogenously and iso-energetically), respectively. Daily feed intake, FCR-, and weight gain were measured. Abdominal fat, liver, and gizzard weights were determined and dry matter, protein, fat content and fatty acid composition of femoro-tibial muscles and liver fat were measured on the 35th, 42nd and 49th days of age. Feeding 45% barley caused a decrease of growth rate ($p\leq0.05$) during the first 4 weeks, which was followed by a rapid, compensatory growth from the 6th week of age ($p\leq0.05$). Both barley and oat supplementation increased protein ($p\leq0.05$), while decreasing fat ($p\leq0.05$) and dry matter ($p\leq0.05$) content of the liver. Feeding of 45% oats in the diet decreased the monounsaturated fatty acid ($p\leq0,05$) and increased the n-6 ($p\leq0,05$), n-3 ($p\leq0,05$) and total polyunsaturated ($p\leq0,05$) fatty acid content of the intramuscular fat owing to the high proportion of soluble non-starch polysaccharides (NSP) in the diet. This might be explained by the more pronounced decrease in digestibility of saturated than unsaturated fatty acids in birds fed a soluble NSP-enriched diet. This result might be caused by the "cage effect" of soluble NSP trapping the bile salts which are more important for the absorption of saturated than polyunsaturated fatty acids. (**Key Words** : Duck, Non-starch Polysaccharides, Barley, Oat, Fatty Acid)

INTRODUCTION

Fatty acid composition of animal tissues depends on different factors such as species, breed, sex, diet and feeding regime. Changes in fatty acid composition have an effect on the quality of meat (Cho et al., 2005). Polyunsaturated fatty acids in the diet are considered as essential dietary lipids in humans and have an important role in prevention of cardiovascular disease (Khanal, 2004).

Non-starch polysaccharides (NSP) have anti-nutritive properties in monogastric animals, e.g. ducks (Jeroch et al., 1995) because soluble viscous NSP is associated with an increase in digesta viscosity (Dusel et al., 1997), and for that reason may reduce the connection between nutrients (e.g. fat) and digestive enzymes (e.g. lipase) and the transport of substrates to the epithelial surface. Alternatively, Choct and Annison (1992) found that the antinutritive effect was attributable to a specific interaction, called "cage effect", rather than the viscosity of soluble NSP. Viscous soluble NSPs have a "matrix" molecular structure and are able to entrap bile salts within the gastrointestinal tract (Ebihara and Schneeman, 1989) which could be the reason for reduced solubilization of fat components and decreased lipid absorption (Smits and Annison, 1996). Choct et al. (1996) reported that digestibility of fatty acids was reduced by feeding of a NSP-enriched diet, but the effect was more severe on saturated than on unsaturated fatty acids in broiler chickens. Our research group also found a reduction in digestibility of crude fat when feeding a soluble NSP-enriched diet to waterfowl (Vetési et al., 1997a).

The β-glucan content of barley is considered the most important anti-nutritive, soluble and viscous NSP of that cereal. The effect might be increased in the presence of arabinoxylans (Jeroch et al., 1992; Jeroch and Danicke, 1995), especially during the first weeks of life.

Recently oats and oat products have become of research interest because of their role in improving carbohydrate metabolism (Bach Knudsen et al., 1990) and reducing cholesterol level (Chen and Anderson, 1986) due to their

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Table 1. Composition and calculated nutrient content of barley- and oat-based diets

Item	Control		Barley		Oats	
	1-14 days	15-49 days	1-14 days	15-49 days	1-14 days	15-49 days
Composition (g kg^{-1})						
Corn	727	748	251	344	456	334
Extr. soya (44%)	85	65	70	57	80	65
Extr. sunflower (45%)	80	65	70	55	80	62
Fishmeal (70%)	40	-	40	-	40	-
Wheat bran	-	60	-	-	-	-
Fat powder (40%)	10	20	60	51	35	4.
Barley	-	-	450	450	-	-
Oats	-	-	-	-	250	450
AP17[1]	16	8	15	10	16	10
Limestone	11	9	11	8	10	7
Biomethin[2]	9	7	11	7	11	12
Biolysin[3]	15	10	15	10	15	8
NaCl	2	3	2	3	2	3
Premix[4]	5	5	5	5	5	5
Calculated nutrient content						
AME_n (MJ kg^{-1} feed)	12.3	12.5	12.2	12.5	12.2	12.5
Crude protein (g)	161.1	130.9	161.0	130.9	161.0	130.7
Crude fiber (g)	31.7	35.5	41.5	40.8	41.5	66.2
Ca (g)	10.1	6.0	9.8	6.0	9.8	5.9
P (g)	7.0	5.1	7.0	5.2	7.0	5.1
Methionine+cystine (g)	7.5	6.0	7.6	5.7	7.6	7.0
Methionine (g)	5.1	3.9	5.2	3.6	5.2	3.9
Lysine (g)	10.5	7.1	10.6	7.2	10.6	6.9
Protein/AME_n (g MJ^{-1})	13.1	10.5	13.2	10.5	13.2	10.5
Calculated fiber composition (g kg^{-1})						
NDF	119.5	134.6	159.5	157.3	160.5	191.3
ADF	45.3	48.8	56.4	54.5	71.6	90.6
ADL	9.1	10.2	13.9	13.4	14.9	18.9
Total NSP	117.7	132.2	153.3	152.0	150.6	175.8
Soluble NSP	16.8	16.5	36.6	35.5	24.2	29.1
Total dietary fiber	135.8	153.0	181.3	178.8	182.4	217.4
Fatty acid composition (% of total fatty acid)						
Fat (g kg^{-1} dry matter)		48.2		50.6		54.3
SAT	-	21.9	-	27.5	-	26.1
MUFA	-	33.9	-	34.4	-	35.4
Total n-6	-	41.9	-	35.5	-	36.0
Total n-3	-	2.2	-	2.4	-	2.3
PUFA	-	44.1	-	37.9	-	38.3

[1] 171 g phosphorus kg^{-1} AP17. [2] 20% DL- Methionine. [3] 20% HCl –Lysine.
[4] Supplied the following (kg^{-1} diet): vitamin A: 11,011 IU; vitamin D_3: 3.300 IU; vitamin E: 29.83 mg: vitamin K_3: 5.39 mg; thiamin: 1.51 mg: riboflavin: 6.75 mg: pyridoxine: 2.90 mg; vitamin B_{12}: 0.010 mg; folic acid: 0.605 mg: niacin: 51.34 mg; Mn 92.1 mg: Fe 34.18 mg: Cu 25.61 mg; Co 0.51 mg; Zn 91.10 mg: I 3.08 mg: Se 0.46 mg.

soluble and/or insoluble NSP content. Oats. and especially oat bran. are rich in soluble dietary fiber (NSP plus lignin) in the form of mixed linked β (1-3; 1-4)-D-glucan. which is an easily fermentable energy source for microflora in the large intestine of the pig (Bach Knudsen et al., 1993). The other main soluble NSP in oats are arabinoxylans, which are primarily responsible for butyrate production in the large intestine (Bach Knudsen et al., 1993), and it was also reported that addition of oat bran to the diet decreased the digestibilities of energy, protein and fat in the terminal ileum of pigs.

The main objectives of the present study were to investigate the effects of soluble NSP-enriched oat and barley on lipid metabolism, especially the fatty acid profile of the femoro-tibial muscles and liver. in table ducks.

MATERIALS AND METHODS

Animals, diets and performance traits

In these experiments K94-breed ducks (Szarvas. Hungary) were used with a sex ratio of 1:1 and 50 birds in each group which were grown following procedures for standard Peking-type duck technology. The ducks were reared under floor management on wheat straw. Light was provided continously in a temperature-controlled room with stock numbers of 1.6 per square meter during the first 2 weeks of age. From the 3rd week of age birds could use a separated, open-air, concrete-based paddock and flume all day. Feed and water were available *ad libitum*. 25 male and 25 female ducklings were grown in one block together and fed pelleted starter diet to the 14th day of age and finisher diet from the 15th to the 49th day of age.

Treatment groups (50 birds/group) were as follows:

i) control (corn based diet)

ii) 45% barley in the diet (isoenergetic and isonitrogenous composition based on AME_n and nitrogen content)

iii) 25% oats in starter and 45% oats in finisher diet (isoenergetic and isonitrogenous composition based on AME_n and nitrogen content).

The reduced oat level in the starter diet was applied to avoid digestion problems in young ducks because of extremely high fiber content.

The composition and calculated nutrient content of the diets are shown in Table 1. Daily feed intake and individual live weight in each week were measured during the experiment. Abdominal fat weight, liver and gizzard weight were determined on the 35th, 42nd and 49th days of age, respectively. Ten randomly selected birds from each group (50 birds/group) were slaughtered by cervical dislocation, bled and dissected. Sexes were separated by individual badges (worn on bird wings) installed after post-hatch sex identification. Grill weight (carcass: without alimentary tract, heart, abdominal fat, legs from tarsus and neck) was determined on the 49th day of age only. Muscles adhering to the femur and tibia (without the skin and subcutaneous fat) and the liver were dissected from each bird, homogenized and deep frozen until chemical analyses.

Chemical analyses

Chemical composition of feed, muscle and liver : Dry matter, crude protein and crude fat content of feed, femoro-tibial (FT) muscles and liver were determined according to Hungarian National Standard Methods (Hungarian Feed Codex, 2000).

Fatty acid composition

Lipid content of the diets was extracted according to the recommendation of Hungarian National Standard Methods (Hungarian Feed Codex, 2000) while that of the muscles

Table 2. Effect of feeding barley and oats on performance traits in table ducks

	Control	45% barley	45% oats
Finishing live weight (g)	2,993±125^{a}	2,977±118^{a}	3,049±105^{a}
Daily weight gain (g, n = 5)			
1-7 days	19±2.8^{a}	17±1.9^{ab}	19±2.0^{a}
8-14 days	43±5.7^{b}	38±3.1^{ba}	43±3.7^{b}
15-21 days	66±4.7^{c}	64±4.7^{c}	65±5.^{c}
22-28 days	86±7.1^{d}	80±9.5^{da}	88±6.7^{d}
29-35 days	63±6.9^{e}	60±7.4^{e}	66±8.8^{c}
36-42 days	83±10.0^{d}	90±9.5^{db}	87±7.0^{d}
43-48 days	60±8.1^{e}	70±10.7^{ea}	61±12.9^{e}
Cumulative weight gain (g/bird)	2,940±163^{a}	2,923±128^{a}	2,997±114^{a}
Average daily feed intake (g, n = 1, 50 birds in each group)			
1-7 days	27.2	27.1	28.9
8-14 days	79.6	75.4	80.7
15-21 days	152.7	144.3	150.9
22-28 days	238.3	238.8	243.1
29-35 days	224.0	229.8	245.9
36-42 days	323.5	362.8	356.7
43-48 days	323.9	328.6	338.8
Cumulative feed intake (g/bird)	9,584	9,848	10,115
FCR (feed conversion rate, kg kg^{-1})			
1-7 days	1.43	1.60	1.52
8-14 days	1.84	2.01	1.88
15-21 days	2.31	2.27	2.33
22-28 days	2.76	2.99	2.76
29-35 days	3.55	3.86	3.74
36-42 days	3.91	4.02	4.12
43-48 days	5.44	4.71	5.55
Cumulative FCR (kg kg^{-1})	3.26	3.37	3.37

Means in colums with different superscripts differ significantly ($p\leq0.05$).

Table 3. Effect of feeding barley and oats on slaughter yield of table ducks (n = 5)

Days of age	Control		45% barley		45% oats	
	Male	Female	Male	Female	Male	Female
Relative liver weight (g kg^{-1} weight)						
35th day	24.3±2.9	23.7±1.4	25.2±3.0	24.3±2.4	20.9±1.0	22.5±1.0^{S}
42nd day	20.1±0.8	21.4±2.8	22.2±1.0^{A}	23.5±2.4	20.5±2.0	21.6±1.0
49th day	21.4±2.1	21.8±3.2	20.4±0.9	22.0±2.3	21.6±1.3	20.9±0.3
Relative abdominal fat weight (g kg^{-1} weight)						
35th day	14.9±3.7	16.9±2.1	14.2±1.5	20.1±0.3$^{T·S}$	13.0±1.9	16.7±4.0
42nd day	17.3±0.9	20.4±1.9^{S}	19.9±2.0^{A}	22.8±2.9	14.9±0.6^{T}	18.5±3.1
49th day	23.2±1.1^{A}	24.3±0.3^{A}	24.2±1.2^{A}	25.7±3.3	18.7±2.7^{A}	22.2±3.4
Relative gizzard weight (g kg^{-1} weight)						
35th day	36.4±3.6	31.9±6.0	40.0±3.6	30.6±0.6^{S}	39.6±4.4	33.7±3.6^{S}
42nd day	35.4±7.0	29.4±2.4	32.5±3.6	30.4±1.4	37.7±3.3	33.2±0.5
49th day	28.0±1.4	25.8±0.7$^{A\ S}$	32.1±3.6	25.9±1.0	30.5±2.4	29.5±3.8
Relative grill weight (g kg^{-1} weight)						
49th day	558.4±10.8	578.9±23.7	575.2±21.6	563.8±15.6	562.2±16.7	552.8±14.3
Average	569±20.5		570±18.8		558±15.2	

^{A} Effect of age, ^{S} Effect of sex, ^{T} Effect of treatment, $^{T·S}$ Effect of treatment and sex interaction. $^{A·S}$ Effect of age and sex interaction (p≤0.05).

and liver was according to Folch et al. (1957). Lipid extracts were then converted to fatty acid methyl esters, separated and analyzed by gas liquid chromatography according to Husvéth et al. (1982). The following fatty acids were identified: C12:0, C14:0, C15:0, C16:0, C16:1 (n-7), C17:0, C18:0, C18:1 (n-9), C18:2 (n-6), C18:3 (n-6), C18:3 (n-3), C20:2 (n-6), C20:3 (n-6), C20:4 (n-6), C22-4 (n-6) and C22:5 (n-3). Results of these fatty acid analyses were used to calculate SAT (saturated fatty acids), MUFA (monounsaturated fatty acids), PUFA (polyunsaturated fatty acids), total n-6 and total n-3 fatty acid content of muscle and liver fat as the most important factors of fatty acid profile.

Statistical analysis

All results were calculated as the means ± SEM of measurements. Statistical analysis was performed by SPSS 14.0 for Windows (ANOVA and Duncan Range Post Hoc test).

RESULTS

Performance traits

Depressed weight gain was found during the first 5 weeks using 45% barley in the diet compared to the control birds, however a significant increase ($p<0.01$) was observed during the last two weeks. Due to that rapid growth the terminal live weight was similar to the control group. A slight increase was found in feed intake and cumulative feed conversion ratio (FCR) of the barley-fed group as compared to the control (Table 2). Similar slaughter weight, higher feed intake and cumulative FCR values were observed in ducks fed the oat-based diet to those in the control group (Table 2).

Treatment, sex and age did not have any significant effect on the relative liver weight ($p>0.05$; Table 3).

Abdominal fat content increased with age in both sexes and each treatment group, but fat deposition was the most intensive during the last week, between the 42^{nd} and 49^{th} days of age ($p<0.001$ male, $p<0.01$ female in control group) Higher weight of abdominal fat pad was observed in the case of female ducks as compared to males on the 35^{th}, 42^{nd} and 49^{th} days of age in each group.

Proportion of abdominal fat in the carcass of ducks fed the oat-based diet decreased from the 35^{th} day of age in both sexes as compared to the control ($p<0.01$ female; $p<0.05$ male) while a slight (not significant) increase was observed in the group fed 45% barley (Table 3).

Grill weight was the same in each group on the 49^{th} day of age (Table 3).

Chemical composition of muscle and liver

Femoro-tibial muscles : Dry matter and fat content of FT muscles decreased with age, while protein content increased between the 35^{th} and 42^{nd} day of age in each group. Later, between the 42^{nd} and 49^{th} day of age, age had no effect on chemical composition of the FT muscles. Significant differences or trends in chemical composition of FT muscles among the treatments were not observed (Table 4).

Liver : Fat content of liver was decreased with age between the 35^{th} and 42^{nd} day of age in the groups fed oat- and barley-based diets. During that period protein content increased, while dry matter content was slightly lower in the oat-fed group. Age-dependent increase in the crude protein and decrease in the dry matter content was found in the barley-fed group one week later (42 to 49 days of age).

Significantly lower fat ($p<0.05$ barley and oat male; $p<0.01$ barley female; $p<0.001$ oat male), and higher crude

Table 4. Effect of feeding barley and oats on chemical composition of femoro-tibial muscles and liver (n = 5)

Days of age	Control		45% barley		45% oats	
	Male	Female	Male	Female	Male	Female
			Femorotibial muscle			
Dry matter (g kg^{-1} wet weight)						
35^{th} day	304.3±27	331.2±29 ^{S}	304.2±30	345.9±28 ^{S}	329.5±29	295.3±25
42^{nd} day	276.6±21	284.2±24 ^{A}	278.9±21	269.4±25 ^{A}	267.5±21 ^{A}	287.3±21
49^{th} day	271.0±18	257.8±21	270.1±20	264.6±20	265.2±23	267.9±18
Crude protein (g kg^{-1} wet weight)						
35^{th} day	641.2±54	602.2±54	623.7±61	670.0±63 ^{T}	686.3±54	694.0±60 ^{T}
42^{nd} day	729.7±68 ^{A}	712.3±69 ^{A}	721.4±58 ^{A}	728.0±68	718.8±59	701.2±61
49^{th} day	748.7±63	743.0±65	701.6±56 ^{S}	745.4±59	734.8±65	711.8±60
Fat (g kg^{-1} wet weight)						
35^{th} day	317.3±19	363.3±28 ^{S}	335.2±24	289.0±21 $^{T \cdot S}$	255.7±19 ^{T}	263.8±24 ^{T}
42^{nd} day	222.7±11 ^{A}	242.3±23 ^{A}	231.7±20 ^{A}	218.0±18 $^{A \cdot T}$	231.7±22	251.5±20
49^{th} day	257.1±25 ^{A}	210.1±22 $^{S A}$	254.4±23	207.4±14 ^{S}	220.5±20 ^{T}	245.6±24 ^{T}
			Liver			
Dry matter (g kg^{-1} wet weight)						
35^{th} day	331.9±29	351.8±27	361.5±33	340.8±35	355.8±31	326.4±30
42^{nd} day	329.4±18	336.9±28	350.1±31	346.6±30	331.8±25	322.7±28
49^{th} day	344.8±21	367.6±35	325.0±29	319.6±24 ^{T}	317.7±29 ^{T}	332.4±29 ^{T}
Crude protein (g kg^{-1} wet weight)						
35^{th} day	734.9±55	726.0±74	681.8±49	733.2±55 ^{S}	738.3±52	724.7±55
42^{nd} day	754.5±43	707.8±69	709.7±45	714.7±47	795.1±62	799.3±46 $^{A\ T}$
49^{th} day	751.4±40	699.0±55	783.4±58 ^{A}	789.3±41 $^{A \cdot T}$	782.1±42	786.0±55 ^{T}
Fat (g kg^{-1} wet weight)						
35^{th} day	223.1±24	232.0±21	266.5±25 ^{T}	224.5±19 ^{S}	227.0±23	233.3±24
42^{nd} day	200.5±19	250.3±23 ^{S}	171.2±16 $^{A \cdot T}$	160.1±14 $^{A \cdot T}$	162.9±19 $^{A\ T}$	158.7±14 $^{A\ T}$
49^{th} day	206.6±21	259.0±26 ^{S}	174.6±16 ^{T}	168.7±18 ^{T}	172.9±16 ^{T}	172.0±18 ^{T}

^{A} Effect of age, ^{S} Effect of sex, ^{T} Effect of treatment, $^{T\ S}$ Effect of treatment and sex interaction. $^{A\ T}$ Effect of age and treatment interaction (p≤0.05).

protein (p<0.01) and lower dry matter (p<0.05) content were found in oat- and barley-fed groups as compared to the control on the 49^{th} day of age.

Fatty acid composition

Fatty acid composition of the FT muscles and liver is presented in Table 5 and 6. The results showed that the applied treatments (45% barley and 45% oat in the diet) had more significant effect on the fatty acid composition of liver than of muscles.

Femorotibial muscles : MUFA content was lower (p<0.05) in males, while total n-6 (p<0.01) and n-3 fatty acids (p<0.001) as well as total PUFA content of FT muscle were higher (p<0.01 male; p<0.05 female), on the oat-based diet on the 49^{th} day of age. The barley-based diet did not have a significant effect on the fatty acid composition in muscle lipids (Table 5).

Liver : Feeding oat-based diet caused significantly lower MUFA content (p<0.01 male; p<0.001 female), and higher total n-6 (p<0.01 male; p<0.001 female), total n-3 (p<0.001), and PUFA content (p<0.01 male; p<0.001 female) of liver compared to the control on the 42^{nd} and 49^{th} days of age. Similar results were found on the 49^{th} day in the 45% barley-fed group (Table 6).

DISCUSSION

Performance traits

Feeding 45% barley in an isoenergetic and isonitrogenous diet caused decreased growth rate and increased FCR in young ducks during the first 5 weeks of age. Owing to the higher amount of entirely undigestible fiber (ADL-content of control: 9.1 g kg^{-1}, 45% barley: 13.9 g kg^{-1} in starter diet), insoluble fiber with poor digestibility (ADF-content of control: 45.3 g kg^{-1}, 45% barley: 56.3 g kg^{-1} in starter diet) and presumably non- or poorly digestible soluble fiber (soluble NSP-content of control: 16.8 g kg^{-1}, 45% barley: 36.6 g kg^{-1} in starter diet), this feeding regime can be considered as nutrient restriction even in the case of higher feed consumption (exceeding amount of non- or poorly digestible fiber reduces digestibility of the other nutrients, as protein and fat). It was followed by more rapid, compensatory growth, a finding which is supported by the results of Vetési et al. (1997b) in table ducks, and in broiler chickens by Wiseman (1988). The first weeks can be considered as an adaptation period for intestinal microorganisms, when a proliferated microbial population can produce adequate amounts of β-glucanase for enzymatic degradation of the fiber components (Jeroch

Table 5. Effect of feeding barley and oats on fatty acid composition of the femoro-tibial muscles (% in total fatty acid, n = 5)

Days of age	Control		45% barley		45% oats	
	Male	Female	Male	Female	Male	Female
Total saturated fatty acids						
35th day	31.8±2.9	30.6±3.0	33.1±3.2	33.3±2.9	31.5±3.0	32.8±3.1
42nd day	32.2±3.3	31.3±2.9	34.2±3.5	34.1±3.2	33.2±3.1	32.1±2.7
49th day	31.0±2.8	31.7±3.0	32.1±3.1	33.2±2.8	31.0±3.0	31.6±3.2
Total monounsaturatd fatty acids						
35th day	50.3±3.6	47.8±3.2	48.3±4.3	47.8±3.2	45.2±4.0	47.3±3.0
42nd day	47.0±3.0	45.9±4.0	48.4±3.5	47.5±4.3	47.2±4.0	47.5±4.2
49th day	50.0±4.0	48.5±2.7	48.3±3.2	47.6±3.0	44.3±3.2 ^{T}	45.8±2.9
Total n-6						
35th day	16.7±1.5	19.8±1.8	16.8±1.5	16.6±1.5	21.4±2.0 ^{T}	18.4±1.7
42nd day	19.5±2.0	21.0±2.0	16.1±1.7	17.4±1.6	18.3±1.9 ^{A}	18.9±2.0
49th day	17.4±1.7	18.6±1.6	17.8±1.9	17.5±1.7	22.1±2.1 $^{A\ T}$	20.9±1.9 $^{A\cdot T}$
Total n-3						
35th day	0.6±0.09	1.3±0.14 ^{S}	1.3±0.11 ^{T}	1.3±0.15	1.3±0.11 ^{T}	1.1±0.12
42nd day	1.1±0.12	1.3±0.12	1.2±0.12	0.7±0.10 $^{A\ S}$	1.1±0.12	0.7±0.10 ^{S}
49th day	1.1±0.10	1.1±0.10	0.8±009 $^{A\cdot T}$	1.4±0.10 $^{T\ S}$	1.7±0.20 ^{T}	1.2±0.12 ^{S}
Total polyunsaturated fatty acids						
35th day	17.3±1.8	21.1±2.1 ^{S}	18.1±1.8	17.9±2.0 ^{T}	22.7±2.0 ^{T}	19.5±2.0 ^{S}
42nd day	20.6±2.2 ^{A}	22.3±2.1	17.3±1.9 ^{T}	18.1±1.90 ^{T}	19.5±2.0	19.5±2.1
49th day	18.5±1.5	19.6±1.6	18.5±1.7	18.9±1.60	23.8±2.3 ^{T}	22.1±1.8 ^{T}

^{A} Effect of age, ^{S} Effect of sex, ^{T} Effect of treatment, $^{T\ S}$ Effect of treatment and sex interaction.
$^{A\cdot T}$ Effect of age and treatment interaction, $^{A\ S}$ Effect of aget and sex interaction ($p\leq0.05$).

and Dänicke, 1995). Contrary to the effect of the barley-based diet, growth depression was not found as an effect of feeding the oat-based diet which is similar to the previous finding of Vetési et al. (1998). A possible explanation might be that the oat-based starter diet contained less soluble NSP compared to the barley-based starter diet (soluble NSP-content of 45% barley: 36.6 g kg^{-1} and 25% oat: 24.2 g kg^{-1} in starter diet). The 45% oats in the diet resulted in higher FCR than the control diet, which may be considered as an anti-nutritive effect owing to the high proportion of non- or poorly digestible non-soluble fiber components (25% oat-ADF: 71.6 g kg^{-1} and ADL: 14.9 g kg^{-1} in starter diet, 45% oat-ADF: 90.6 g kg^{-1} and ADL: 18.9 g kg^{-1} in finisher diet).

Organ weight

Feeding barley-based diet slightly improved the abdominal fat deposition, but did not affect the relative weight of liver, gizzard and grill carcass. Wiseman (1988) also observed that compensatory growth is associated primarily with fat deposition in broiler chickens. Mollison et al. (1984) found that early dietary fat restriction caused an increase in abdominal adipose tissue weight at 7 weeks in broiler chickens. Fat deficiency at a young age may also account for the increase of abdominal fat deposition in the present study since a soluble NSP-enriched diet (and higher consumption rate) can trap the bile acids and reduce fat digestibility.

The oat-based diet caused slightly lower abdominal fat content as compared to control birds and the difference was more pronounced in male ducks, because of the lack of compensatory growth. The high dietary fiber content (25% oat: 182.4 g kg^{-1} in starter diet, 45% oat: 217.4 g kg^{-1} in finisher diet) of the diet improved the weight of gizzard since it may stimulate the function of this organ as also found by Vetési and Bokori (1990) in geese which consumed green alfalfa as compared to a cereal grain-based diet.

Organ composition

The barley-based diet did not have any marked effect on chemical and fatty acid composition of femoro-tibial muscles. However, the oat-based diet decreased the MUFA and increased n-6 and n-3 PUFA content of the intramuscular fat. The barley- and oat-based diets significantly modified the liver fatty acid composition. Previously it was found (Bartov, 1992) that size, fat content and fatty acid composition of the liver responded to feed withdrawal, while there were no changes in concentration or fatty acid composition of fat in breast and thigh muscles (Hulan et al., 1989). These results also suggest that the liver is a more sensitive indicator of changes in lipid metabolism than muscle. In present study 45% barley and 45% oats in the diet increased protein while decreasing fat and dry matter content of liver. The quantitative changes in the chemical composition, namely decreased fat content, of liver caused by barley- and oat- based diets occurred

Table 6. Effect of feeding barley and oats on fatty acid composition of liver tissues (% in total fatty acid, n = 5)

Days of age	Control		45% barley		45% oats	
	Male	Female	Male	Female	Male	Female
Total saturated fatty acids						
35^{th} day	36.5 ± 2.9	37.2 ± 3.1	39.1 ± 2.9	37.0 ± 3.0	30.5 ± 2.5^{T}	39.0 ± 3.5^{S}
42^{nd} day	$38.1\pm.4$	38.9 ± 2.6	38.3 ± 3.7	38.6 ± 2.7	39.3 ± 3.2^{A}	40.4 ± 3.4
49^{th} day	35.5 ± 3.4	39.5 ± 3.7	38.8 ± 2.9	38.4 ± 3.1	37.4 ± 2.8	38.3 ± 2.5
Total monounsaturated fatty acids						
35^{th} day	40.9 ± 4.0	41.0 ± 4.3	44.1 ± 4.2	40.4 ± 4.6	40.8 ± 3.5	36.9 ± 3.7
42^{nd} day	36.6 ± 3.5	41.2 ± 4.0	40.0 ± 3.8	42.1 ± 3.9	$31.1\pm2.9^{A\ T}$	$28.8\pm2.1^{A\cdot T}$
49^{th} day	38.80 ± 3.7	42.0 ± 4.0^{S}	$29.2\pm2.5^{A\ T}$	$30.6\pm2.9^{A\ T}$	31.4 ± 3.0^{T}	$27.1\pm2.5^{T\ S}$
Total n-6						
35^{th} day	20.6 ± 2.5	19.4 ± 2.1	15.1 ± 2.0^{T}	20.3 ± 1.9^{S}	17.9 ± 2.2	20.8 ± 2.0
42^{nd} day	22.1 ± 1.8	17.6 ± 1.6^{S}	18.7 ± 2.0^{T}	16.6 ± 1.7	$25.6\pm1.9^{A\ T}$	$27.1\pm2.2^{A\cdot T}$
49^{th} day	21.9 ± 1.9	16.2 ± 1.4^{S}	$27.8\pm2.5^{A\ T}$	$27.3\pm2.2^{A\ T}$	27.2 ± 2.6^{T}	30.7 ± 2.5^{T}
Total n-3						
35^{th} day	1.9 ± 0.2	2.1 ± 0.1	1.7 ± 0.2^{T}	1.9 ± 0.1^{T}	2.2 ± 0.3	2.4 ± 0.2
42^{nd} day	3.0 ± 0.3	2.3 ± 0.3^{S}	2.7 ± 0.2	2.3 ± 0.3	$3.6\pm0.3^{A\ T}$	$3.3\pm0.3^{A\cdot T}$
49^{th} day	2.8 ± 0.3	2.2 ± 0.2^{S}	$3.8\pm0.3^{A\ T}$	$3.4\pm0.4^{T\ A}$	3.9 ± 0.4^{T}	3.6 ± 0.4^{T}
Total polyunsaturated fatty acids						
35^{th} day	22.5 ± 2.0	21.4 ± 2.3	16.7 ± 1.9^{T}	22.2 ± 2.0^{S}	20.1 ± 2.2	23.2 ± 2.1
42^{nd} day	25.1 ± 2.3	19.9 ± 1.8^{S}	21.3 ± 2.5^{T}	18.9 ± 1.6	$29.2\pm2.1^{A\ T}$	$30.5\pm3.2^{A\cdot T}$
49^{th} day	24.6 ± 2.0	18.4 ± 1.9^{S}	$31.7\pm2.8^{A\ T}$	$30.7\pm3.0^{A\ T}$	31.1 ± 2.6^{T}	34.3 ± 3.2^{T}

^{A} Effect of age, ^{S} Effect of sex, ^{T} Effect of treatment, $^{T\ S}$ Effect of treatment and sex interaction, $^{A\ T}$ Effect of age and treatment interaction ($p\leq0.05$).

simultaneously with the qualitative changes in fatty acid composition during the last three weeks of the experiment. Contrary to the decrease in the fat and MUFA content of the liver, the barley- and oat-based diets caused an increase in total n-6 fatty acids and total n-3 fatty acid content. These changes cannot be explained by the differences in fatty acid composition of the diets, since the barley- and oat-based diet contained slightly more SAT, MUFA, total n-3 fatty acids and less or similar total n-6 fatty acids and PUFA than the control (Table 1). It may be explained by the results of Choct et al. (1996) who reported more pronounced decrease in the digestibility of saturated than unsaturated fatty acids of birds fed an increasing amount of soluble NSP in the diet. That result might be caused by the "cage effect" of soluble NSP trapping the bile salts which are more important for the absorption of saturated fatty acids than PUFA.

Reduction of fat and increase of PUFA, mainly n-3 fatty acid, content in meat is a focus of research. However, although poultry meat contains low fat and a high amount of unsaturated fatty acids, further modification would be advantageous. Most of the vegetable oils increase the linoleic acid content of poultry meat without negative effect on its flavour, but they usually do not increase its EPA and DHA level (Hawrysh et al., 1980; Salmon et al., 1981; Chanmugam et al., 1992). In our study oats have increased n-6 and n-3 content of the femoro-tibial muscles and liver fat.

Lipid peroxidation is considered to be an important factor in affecting flavor, stability and nutritive value of poultry meat. There is a positive correlation between oxidative stability of poultry meat and dietary PUFA levels (Manilla, 1999). Lopez-Bote et al. (1998) reported that an oat-based diet enhanced oxidative stability of chicken meat, so they suggest oats as a natural antioxidant.

Owing to its positive effect on lipid composition of table duck meat, liver and antioxidant activity, an oat-based diet would be a possible way of improving waterfowl meat quality.

CONCLUSIONS

Barley and oats modify the lipid metabolism, since barley improved the abdominal fat deposition while oats reduced weight of abdominal fat pad in ducklings.

Barley and oats as a high proportion of the diet (45% in finisher diet) modified the chemical composition of liver but did not have an effect on muscle composition. An oat-based diet decreased MUFA and increased n-6, n-3 PUFA content of the intramuscular fat, and significantly modified the liver fatty acid composition.

In summary, oat-based diet would be a possible way to improve waterfowl meat quality owing to the proven positive effect of oats on lipid composition of table duck meat and liver.

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