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Effects of Dietary Fat Source on Tissue Fatty Acid Composition of Carcasses From Heat-distressed Broilers

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Abstract: Male broilers (commercial strain) were used to evaluate the effects of diets differing in fat source on fatty acid composition of carcasses of heat-distressed broilers. Dietary treatments included corn oil, animal fat (tallow), fish oil and a dry blended (animal and vegetable) fat product fed in either a thermoneutral (TN) or heat-distressed (HD) environment. Diets were isocaloric with each containing an equal number of calories from fats. Birds were reared in floor brooder pens and fed experimental diets from Day 1 to 21 and then assigned the same dietary treatments in one of two environmentally controlled chambers. One chamber was maintained at 23.9 oC, whereas birds in the second chamber were exposed to 8 hours of 23.9 oC, 4 hours of 23.9 to 35 oC, 4 hours of 35 oC and 8 hours of 35 to 23.9 oC. At 49 days of age, following 12 hour fast, birds were weighed and six birds from each treatment slaughtered and processed into market parts and abdominal fat pad harvested. The carcass fatty acid composition mainly reflected dietary fatty acid content with no diet x environmental temperature interaction. Data suggest that both fat source and environmental temperature influence fat deposition gain and that fat source influences tissue fatty acid composition.

Key words: broilers, heat distress, dietary fats, fatty acids

Introduction

Maximum growth rate of poultry is influenced by several factors. Ambient temperature and relative humidity have been cited as environmental factors that have a major impact on production (NRC, 1981). Domestic birds, like all homeotherms, maintain a relatively constant body temperature through physiological responses that equilibrate heat gain and loss. In growing poultry, heat is generated from basal metabolism and cellular metabolism for growth. Metabolic heat, combined with heat absorbed from the micro-environment constitutes the total heat load experienced by the bird. With an increase in ambient temperature above the zone of thermoneutrality (21-26 C), birds have great difficulty in removing the body heat they generate or absorb from the environment (Smith and Oliver, 1971). This inability to dissipate heat in a high environmental temperature-relative humidity situation results in heat prostration (Reece, *et al.*, 1972). In addition, it has been shown that feed consumption may be reduced by as much as 29 % when birds are reared in a cycling high temperature environment of 23.9 to 35 C versus a constant thermoneutral temperature of 23.9 C (Smith *et al.*, 1995). The decrease in feed consumption can result in energy inadequacy. Fats are high-energy components of poultry diets and are generally used to increase the energy contents of feed in a heat stress situation where additional energy is needed. An added benefit of supplemental fat, in the diets of heat stressed market age broilers, is the fact that fats have a lower heat increment of the diet and as such will contribute less heat to the total heat load being experienced by birds under these conditions. Addition of fat to poultry diets generally results in an increase in energy concentration, improved productivity, and improved feed efficiency. It has been shown that feeding fat to poultry apparently increases digesta retention time and as a result allows for a more complete utilization of other feed components (Mateos and Sell, 1981). Other positive attributes of feeding fats may lie in the fatty acid composition and their effects on the immune system. Fritche *et al.* (1991), demonstrated that feeding chicks an n-3 fatty acid-rich diet significantly enhanced antibody production. An energy deficiency during heat stress caused by reduced feed intake, resulting in turn from the discomfort of dietary heat increment, may be alleviated by manipulating dietary constituents with low heat increment such as fat (Waldroup *et al.*, 1976: Dale and Fuller, 1979).

The purported merits of diets rich in monounsaturated and polyunsaturated fatty acids for humans have generated research in producing meats high in these types of fatty acids. It has been shown that fatty acids from the diet are deposited in the tissues of monogastric animals, such as poultry, primarily maintaining the same structure. Therefore, with proper adjustment, it may be possible to determine the eventual fatty acid make-up of poultry tissue dependening on the types of fat used in the diet.

The study reported here was designed to investigate the influence of different dietary fats on the fatty acid composition of carcasses from broilers reared under different thermal conditions.

Materials and Methods

Animals and Diets: Two hundred and forty, 1-day old male broilers (commercial strain) were used in this experiment. Birds were randomly assigned to four treatments with sixty birds per treatment and raised on floor pens in a brooder house for 21 days posthatching. The four dietary treatments were achieved by using one of four different fat sources in the formulation of the experimental diets (Table 1): corn oil, animal fat, fish oil, and a dry blended (animal and vegetable) fat product. Diets were formulated to contain 3066 kcal/kg of metabolizable energy and 22.3 % crude protein and were isocaloric with 14.7 % of the calories from the individual fat source. Chicks were allowed *ad libitum* access to feed and water.

Growth Environment: On day 22 of the experiment, 30 chicks per treatment were randomly placed in individual 60 x 40 x 45 cm wire cages within each of two environmental chambers under controlled temperature and humidity. Each chamber was 14.6 x 7.3 m and contained four rows of single-level cages placed 91 cm off the floor. Cages in each chamber were fitted with feed and cup-type water dispensing equipment. During week 4 of the experiment, birds were adapted to chamber surroundings and peak chamber temperature in the cycling high temperature environment increased at the rate of 2 oC per day to a high of 35 oC. The temperature in one chamber was maintained at 23.9 oC constant temperature (thermoneutral, TN). For each 24 hour period in the second chamber, the environmental temperature cycled from a low of 23.9 oC to a high of 35 oC (heat distress, HD). Birds were exposed to 8 hours of 23.9 oC, 4 hours of 23.9 to 35 oC, 4 hours of 35 oC, and 8 hours of 35 to 23.9 oC. The relative humidity in the HD environment peaked at 60% during the daily heat episodes. Birds were weighed weekly and feed consumption determined

Carcass Preparation: Birds were maintained in their respective growth environments until Day 49. Following a 12-hour period in which feed was removed but water continued to be available, twelve birds from each treatment and growing environment were randomly selected and slaughtered. Each bird was hung on rail, stunned with a hand-held electrical knife, and killed by severing the jugular vein. Following a4-minute bleeding time, each carcass was immersed in a scalding vat at 60 oC for two minutes, feathers removed by placing in a rotary drum picker for 30 seconds, and the carcasses manually eviscerated. Carcasses were chilled in ice water for approximately one hour, drained for ten minutes, weighed, and cut up into various parts after hand separation of abdominal fat. Abdominal fat comprised the fat surrounding the bursa of Fabricius, cloaca, and abdominal muscles. Thighs and legs were obtained by separating the thigh from the back at the joint between the femur and the ileum, separating the tibia and shank at the hock joint, and finally, separating the thigh and leg at the femur-tibia joint. The breast portion was obtained by cutting through the ribs, thereby separating the breast portion from the back.

Fatty Acid Analysis: Parts, (breast, representing white meat and thigh representing dark meat), including bones, were separately ground in a Century meat grinder (General Slicing, Murfreesboro, TN 37130) fitted with a 2-mm screen. Samples were removed from each part and fat extracted by Soxhlet apparatus. Following extraction, fatty acid analysis was carried out using the one-step methanol-benzene method of Sukhija and Palmquist (1988).

Statistical Analysis: Data were subjected to analysis of variance using the General Liner Models procedures of SAS software (SAS Institute, 1987) with the main effects being fat source and environment. Least square treatment means were compared if a significant F statistic (5 % level of probability) was detected by analysis of variance (Steele and Torrie, 1960).

Results

Examination of the selected fatty acid pattern of the different diets indicates that in general, the fatty acid pattern of the fat from various sources (Table 2) were similar to that seen in the diets (Table 3). The fatty acid analysis of each part (breast and thigh) as well as abdominal fat pad, is reported. Table 4 shows the effect of dietary fat source and bird growing temperature on the total fatty acids, monounsaturated and polyunsaturated fatty acid content of broiler breast meat. Overall, the breast meat from birds grown in the heat distress environment had lower ($p < 0.03$) total fatty acids than that of their counterparts raised in the thermoneutral environment. The main effect of fat source was highly significant ($P < 0.0001$) for each fatty acid examined however, there were no temperature X fat interaction. The greatest levels of C16:0 and C18:0 representing the saturated fatty acids, were recorded for the dry blended fat product with animal fat having similar levels of C16:0. The monounsaturated fats (represented by C18:1), was highest in the breast meat from birds fed animal fat and lowest in those on the

Table 1: Composition of experimental diets

Ingredient	%
Corn	51.35
Soybean meal 49 %	36.5
Fata	4.7
Dicalcium phosphate	2.0
Limestone	1.0
Vitamin-trace mineral mixb	1.0
Salt	0.4
DL-methionine	0.15
Coccidiostat	0.1
Sandc	2.8

[a]Fat sources were either corn oil, animal fat, fish oil or a dry blend of animal and vegetable fat. Amounts varied in order to make diets isocaloric.
[b]Supplied per kilogram of diet: copper, 8 mg; iodine, 0.4 mg; iron, 100 mg; selenium, 0.3 mg; zinc, 75 mg; vitamin A (retinyl acetate), 4540 IU; vitamin D3, 1543 ICU; vitamin E, 15 IU; choline, 284 mg; niacin, 34 mg; d-panthothenic acid, 5.7 mg; menadione, 0.85 mg; vitamin B12, 0.01 mg; biotin, 0.1 mg; folic acid, 0.5 mg; thiamine, 0.6 mg.
[c]Amount of sand varied at the expense of fat in order to make diets isocaloric.

Table 2: Fatty acid composition of fats from different sources (%)

Fatty Acid	Corn oil	Animal fat	Fish oil	Dry blend1
C16:0	11.2	22.7	13.4	27.5
C18:0	2.0	8.9	2.8	63.0
C18:1	26.8	45.7	12.8	3.0
C18:2	59.5	14.4	1.7	ND2
C18:3	0.6	1.3	1.6	ND
C20:4	ND	ND	0.4	ND

[1]Dry blend of animal and vegetable fat
[2]None detected

Table 3: Fatty acid composition of experimental diets (%)

Fatty Acid	Corn oil	Animal fat	Fish oil	Dry blend1
C16:0	14.05	20.98	15.34	20.30
C18:0	1.70	6.84	2.80	33.75
C18:1	22.76	34.16	14.33	9.05
C18:2	24.21	24.21	17.74	24.21
C18:3	1.87	1.67	2.18	1.18
C20:4	ND2	ND	ND	ND
C20:5	ND	ND	ND	ND

[1]Dry blend of animal and vegetable fat
[2]None detected

fish oil diet. The greatest level of polyunsaturated fatty acids found in the breast meat(Table 5), was represented by C18:2. Corn oil had the highest amount ($p < 0.05$), while all other fat sources had similar amounts. Breast meat from birds on the fish oil diet had the highest level of C20:5 with the tissue from birds on all other fat sources having very minute amounts.

The proportion of fatty acids from thigh muscle, representing the dark meat, is shown in Tables 6 and 7. Compared to the breast tissue (white meat), tissue from thigh meat had twice as much total fatty acid (mg/g). Heat distress apparently elevated C16:0 and C18:0 fatty acids, while polyunsaturated fatty acids were largely unaffected by temperature. As with the breast meat tissue, the main effect of fat source was highly significant for fatty acid content. In general, the proportion of fatty acids from the different sources was similar to that of the

Table 4: Effect of dietary fat source and growing temperature1 on total, saturated, and monounsaturated fatty acid composition of broiler breast meat.

Fat source	Total (mg/g)		C16:0 (%)		C18:0 (%)		C18:1 (%)	
	TN	HD	TN	HD	TN	HD	TN	HD
Corn Oil	110.4	109.4	19.2	20.2	7.83	8.17	30.0	31.2
Animal fat	174.1	150.1	21.8	22.5	7.39	8.06	40.7	41.4
Fish oil	114.0	95.5	20.6	21.3	7.07	8.25	24.3	24.9
Dry blend2	104.3	76.8	23.2	22. 9	10.53	10.79	32.1	29.6
SEM			6.48	0.23	0.26		0.86	

ANOVA	df	Probabilities			
Temp	1	.03	.09	.07	.98
Fat	3	.0001	.0001	.0001	.0001
Temp x Fat	3	.66	.38	.77	.61
Main Effects					
Temperature					
TN		125.7a	21.2	8.21b	31.8
HD		107.9b	21.7	8.87a	40.0
Fat					
Corn oil		108.9b	19.6c	8.00b	30.4b
Animal fat		162.1a	22.1a	7.73b	41.1a
Fish oil		105.1b	20.9b	7.63b	24.5c
Dry blend		90.6b	23.1a	10.66a	30.8b

[1]TN = thermoneutral, 23.9 0C; HD = heat distress, 23.9 - 035 C
[2]Blend of animal and vegetable fat
abcMeans in columns within main effect differ significantly (P< 0.05)

Table 5: Effect of dietary fat source and growing temperature1 on polyunsaturated fatty acid composition of broiler breast meat.

Fat Source	C18:2 (%)		C18:3 (%)		C20:4 (%)		C20:5 (%)	
	TN	HD	TN	HD	TN	HD	TN	HD
Corn oil	31.1	28.4	0.58	0.66	2.49	2.09	0.049	0.137
Animal fat	16.4	16.4	0.68	0.66	1.47	1.74	ND2	0.017
Fish oil	14.8	15.9	0.89	0.82	1.20	0.87	3.77	2.96
Dry blend3	15.8	16.4	0.55	0.46	2.70	3.03	ND2	0.014
SEM	0.83		0.048		0.199			0.119

ANOVA	df	Probabilities			
Temp	1	.80	.63	.90	.25
Fat	3	.0001	.001	.0001	.0001
Temp x Fat	3	.58	.74	.62	.13
Main Effects					
Temperature					
TN		19.5	0.68	1.98	0.96
HD		19.1	0.64	1.97	0.70
Fat					
Corn oil		29.8a	0.62b	2.32ab	0.097b
Animal Fat		16.4b	0.67ab	1.60bc	0.009b
Fish oil		15.1b	0.86a	1.03c	3.40a
Dry blend		16.1b	0.51b	2.87a	0.007b

[1]TN = thermoneutral, 23.9 0C; HD = heat distress, 23.9 - 035 C
[2] ND = None detected
[3] Blend of animal and vegetable fat
[a]bcMeans in columns within main effect differ significantly (P< 0.05)

Table 6: Effect of dietary fat source and growing temperature1 on total, saturated, and monounsaturated fatty acid composition of broiler thigh meat

Fat source	Total (mg/g)		C16:0 (%)		C18:0 (%)		C18:1 (%)	
	TN	HD	TN	HD	TN	HD	TN	HD
Corn Oil	262.2	279.2	19.7	23.3	6.64	7.83	30.9	35.8
Animal fat	305.6	327.2	21.5	23.8	6.45	7.11	39.9	41.9
Fish oil	265.2	267.0	22.7	24.5	7.19	7.75	27.0	27.6
Dry blend2	276.1	258.4	24.1	25.2	9.36	10.64	35.0	34.0
SEM		15.84		0.58		0.23		0.99

ANOVA	df	Probabilities			
Temp	1	.77	.003	.002	.20
Fat	3	.21	.03	.0001	.0001
Temp x Fat	3	.89	.67	.74	.39
Main Effects					
Temperature					
TN		277.3	22.0b	7.41b	33.2
HD		283.3	24.2a	8.39a	35.1
Fat					
Corn oil		269.8	21.4b	7.23b	33.2b
Animal fat		316.4	22.7ab	6.78b	40.9a
Fish oil		265.7	23.5ab	7.46b	27.2b
Dry blend		267.3	24.6a	10.0a	34.5b

[1]TN = thermoneutral, 23.9 0C; HD = heat distress, 23.9 - 035 C

[2] Blend of animal and vegetable fat

abMeans in columns within main effect differ significantly (P< 0.05)

Table 7: Effect of dietary fat source and growing temperature1 on polyunsaturated fattyacid composition of broiler thigh meat.

Fat source	C18:2 (%)		C18:3 (%)		C20:4 (%)		C20:5 (%)	
	TN	HD	TN	HD	TN	HD	TN	HD
Corn oil	22.3	18.6	0.57	0.50	0.87	0.67	0.023	0.007
Animal fat	12.3	14.8	0.62	0.65	0.64	0.66	0.009	ND2
Fish oil	13.4	12.5	1.14	1.01	0.46	0.28	2.52	1.65
Dry blend3	16.8	16.5	0.97	0.96	1.26	1.33	0.152	0.067
SEM		0.86		0.071		0.069		0.079

ANOVA	df	Probabilities			
Temp	1	.59	.65	.39	.02
Fat	3	.0001	.0001	.0001	.0001
Temp x Fat	3	.23	.95	.58	.01
Main Effects					
Temperature					
TN		16.2	0.82	0.81	0.68a
HD		15.7	0.77	0.76	0.38b
Fat					
Corn oil		20.6a	0.53b	0.77b	0.016b
Animal Fat		13.6b	0.63b	0.65bc	0.005b
Fish oil		13.0b	1.05a	0.38c	2.12a
Dry blend		16.6ab	0.96a	1.30a	0.109b

[1]TN = thermoneutral, 23.9 0C; HD = heat distress, 23.9 - 035 C

[2] ND = None detected

[3] Blend of animal and vegetable fat

[a]bcMeans in columns within main effect differ significantly (P< 0.05)

Table 8: Effect of dietary fat source and growing temperature1 on total, saturated, and monounsaturated fatty acid composition of broiler abdominal fat pad

Fat source	Total (mg/g)		C16:0 (%)		C18:0 (%)		C18:1 (%)	
	TN	HD	TN	HD	TN	HD	TN	HD
Corn Oil	1008	1086	18.4	18.8	6.54	6.74	29.4	28.2
Animal fat	1049	1049	23.3	24.0	7.28	7.76	41.2	39.0
Fish oil	1025	881	21.9	21.0	7.95	7.06	25.1	23.4
Dry blend2	1033	978	24.8	24.8	10.43	10.81	36.1	32.2
SEM		22.1		0.49		0.24		0.80
ANOVA	df			Probabilities				
Temp	1	.28		.93		.89	.04	
Fat	3	.06		.0001		.0001	.0001	
Temp x Fat	3	.05		.83		.36	.79	
Main Effects								
Temperature								
TN		1029		22.1		8.05	32.9	
HD		998		22.1		8.14	31.0	
Fat								
Corn oil		1045		18.6c		6.64b	28.8c	
Animal fat		1049		23.6a		7.52b	40.1a	
Fish oil		951		21.3b		7.48b	24.2d	
Dry blend		1005		24.8a		10.63a	34.2b	

[1] TN = thermoneutral, 23.9 0C; HD = heat distress, 23.9 - 035 C
[2] Blend of animal and vegetable fat
[a]bcdMeans in columns within main effect differ significantly (P< 0.05)

Table 9: Effect of dietary fat source and growing temperature1 on polyunsaturated fatty acid composition of broiler abdominal fat pad

Fat source	C18:2 (%)		C18:3 (%)		C20:4 (%)		C20:5 (%)	
	TN	HD	TN	HD	TN	HD	TN	HD
Corn oil	35.0	38.1	1.27	1.06	ND2	ND	0.568	0.001
Animal fat	16.6	16.6	1.40	1.32	ND	ND	0.001	0.381
Fish oil	15.0	14.8	1.87	1.94	ND	ND	3.76	2.27
Dry blend3	15.2	15.3	1.32	1.40	ND	ND	ND	0.079
SEM		0.71		0.10		ND		0.24
ANOVA	df			Probabilities				
Temp	1		.38		.80	ND		.47
Fat	3		.0001		.001	ND		.0001
Temp x Fat	3		.53		.83	ND		.05
Main Effects								
Temperature								
TN			20.5		1.46	ND		1.08
HD			21.2		1.41	ND		0.814
Fat								
Corn oil			36.6a		1.17b	ND		0.297b
Animal Fat			16.6b		1.36b	ND		0.190b
Fish oil			15.3b		1.88a	ND		3.08a
Dry blend				15.0b		1.36b	ND	
0.395b								

[1]TN = thermoneutral, 23.9 0C; HD = heat distress, 23.9 - 035 C
[2] ND = None detected
[3] Blend of animal and vegetable fat
[a]bMeans in columns within main effect differ significantly (P< 0.05)

breast meat. Abdominal fat pad, representing carcass depot fat, had a high amount of total fatty acids as would be expected (Table 8). Proportionally, the saturated and monounsaturated fatty acids were similar to that found in the muscle tissues. The proportion of polyunsaturated fatty acids in the abdominal fat pad (Table 9) largely reflected the dietary composition. As with the other tissues, C18:2 was the highest polyunsaturated fatty acid present with corn oil having the greatest percentage. The presence C20:4 not be detected in the abdominal fat pad.

Discussion

Proportionally, tissue fatty acid composition of broiler carcasses reflected the fatty acid composition of the fats used in the various diets. This was exemplified best in the fatty acid content of the abdominal fat pad in which the presence of C20:4 was not detected and C20:5 was almost non-existent. It has been reported that C18:1 is the major fatty acid of carcass fat (Ajuyah *et al.*, 1991). In this experiment, C18:1 was also the predominant fatty acid in breast and thigh meat as well as in the abdominal fat pad. The inclusion of fish oil as a fatty acid source had a significant effect on the C20:5 content of the various parts. This is consistent with the work of Scaife *et al.*, (1994) which showed that marine oil significantly elevated C20:5 in adipose tissue.

The use of fat in the diets of heat distressed birds is recommended as a method of increasing energy intake without contributing to the problem of added heat from the heat increment of the diet. In this study, there was no temperature X fat interaction for the fatty acid composition of carcass tissues with the exception of C20:5 . The main effect of temperature was significant for the saturated fatty acids in the muscle tissues with the birds in the heat distressed environment having greater levels of C16:0 and C18:0. This is consistent with the work of Ain Baziz *et al.* (1996) which indicated that under hot conditions saturated fatty acid content increased primarily though the higher concentration of palmitic acid.

Results of this experiment suggest that dietary fatty acid content is an indicator of carcass fatty acid composition. In addition, rearing broilers under growing conditions that can lead to heat distress may have an undesirable effect on carcass composition by enhancing the saturated fat content.

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