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Effects of the Time of the Switch from an Unsaturated (Sunflower Oil) to a Saturated (Tallow) Dietary Fat Source on Performance and Carcass Fatty Acid Profile of Broiler Chickens

Research Article

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ABSTRACT

A total of 700 day old female broiler chicks (Ross 308) were distributed into seven groups in a completely randomized design with five replicates, and 20 chicks in each replicate. Dietary treatments, time of the switch from an unsaturated sunflower oil (SFO) to a saturated tallow (T) dietary fat source, were: 1) SFO for the entire growth period (6 weeks), 2) SFO for 5 weeks followed by T for last week, 3) SFO for first 4 weeks followed by T for last 2 weeks, 4) SFO for first 3 weeks followed by T for last 3 weeks, 5) SFO for first 2 weeks followed by T for last 4 weeks, 6) SFO for first 1 week followed by T for last 5 weeks and 7) T for the entire growth period. Chicks had free access to water and experimental diets during the experimental periods. All diets were calculated to be isocaloric and isonitrogenous. Body weight and feed intake of chicks fed different diets were recorded at 21 and 42 days. At the end of experiment (on 42 day), two birds were randomly selected from each pen and slaughtered and then breast, leg and thigh muscles and abdominal fat were sampled to determine fatty acid profile. The SAS general linear models (GLM) procedure was used for the statistical analysis of data. There was statistically significant differences between dietary treatments for body weight, feed intake and feed conversion ratio during the period from 22 to 42 d and the entire growth period, with a higher values of body weight for chicks fed diets supplemented with SFO throughout the entire growth period (P<0.05). The lower feed conversion ratio was observed in chicks fed T-based diet for the entire growth period. Chicks with more access to T-based diet during the feeding program had significantly higher amounts of saturated and monounsaturated fatty acids in their carcass compared to those fed SFO based diets (P<0.05). Shifting from SFO to T diet just for a few weeks time was capable in altering the profile of fatty acids in tissues toward a more saturated pattern.

KEY WORDS broiler, carcass fatty acid profile, dietary fat source.

INTRODUCTION

The most practical method for increasing the energy density in poultry diet is trough the addition of fats and oils (Peebles *et al.* 2000). It was reported that fat metabolism and deposition in poultry could be affected by different dietary fats and fatty acids (Sanz *et al.* 2000; Pesti *et al.* 2002; Ferrini *et al.* 2008). Tallow (T), as a processing by products, is available for the poultry industry as a cheaper dietary fat source. However, oils form plant origin, such as sunflower oil (SFO), contain high levels of unsaturated fatty acids (UFAs) and are more completely digested by fowl than animal fats (Wiseman and Salvador, 1991; Leeson and Atteh, 1995). In relation with the development of cardiovascular disease in humans, there are concerns regarding the use of animal fats as feed ingredients for production animals, causing a shift toward the use of vegetable oils (Walker *et al*. 2005). However, when fat supplementation is performed in broiler diets the effects on carcass fat quality must be taken into account, because dietary fatty acids are incorporated with little change into the body fat (Olomu and Baracos, 1991; Scaife *et al*. 1994). Changes in the fatty acid profile of fat deposits in chickens can result in a modification of the carcasses' aspect. Carcasses score indicated that they are firmer and drier when feeds are supplemented with T (Edwards *et al*. 1973; Wongsuthavas *et al*. 2008). Conversely, chickens fed on unsaturated oils show carcasses with softer fats. In broiler chickens, the oily fat problem encountered in slaughter houses causes technological incidents. There is a lack of enough information about the effects of shifting from an unsaturated fat to saturated one on the growth and fatty acid composition of the carcass in broiler chickens. Thus, the objective of this study was to investigate the effect of the time of the switch from an unsaturated (SFO) to a saturated (T) dietary fat source on performance and carcass fatty acid profile of broiler chickens.

MATERIALS AND METHODS

Birds and diets

Seven hundred one-day-old Ross female broiler chicks were randomly distributed into seven groups with four replicates of 10 birds each and were fed diets supplemented with SFO and T according to a balanced completely randomized design. Dietary treatments were: 1) SFO for the entire growth period (6 weeks), 2) SFO for 5 weeks followed by T for last week, 3) SFO for first 4 weeks followed by T for last 2 weeks, 4) SFO for first 3 weeks followed by T for last 3 weeks, 5) SFO for first 2 weeks followed by T for last 4 weeks, 6) SFO for first 1 week followed by T for last 5 weeks and 7) T for the entire growth period. The experimental diets were formulated to be isoenergetic and isonitrogenous for both starting and finishing periods (Table 1). Diets were presented as mash and the chicks had free access to water and experimental diets during the experimental periods. Fatty acid content of SFO, T and diets was determined following the methodology described by Folch *et al*. (1957) and Metcalf *et al*. (1966), Table 2.

Performance measurement and fatty acid determination

Mean body weight and feed intake per cage were measured at 21 and 42 days.

Table 1 Ingredient and nutrient composition of the experimental diets

Feed ingredients (%)	Starter diets (days 0-21)		Finisher diets (days 22-42)	
	Sunflower oil	Tallow	Sunflower oil	Tallow
Corn	38.83	43.99	47.36	48.98
Soybean meal	25.95	26.58	25	25
Fish meal	8	8.2	6.79	7.05
Wheat	11.97	9.5	8	8.19
Wheat bran	7.03	3.54	5.17	3.13
Fat	5	5	5	5
DCP	0.79	0.78	0.25	0.27
Oyster	0.71	0.70	0.86	0.81
Salt	0.10	0.1	0.20	0.20
$NaHco_3$	0.20	0.20	0.06	0.06
DL-methionine	0.25	0.25	0.25	0.25
Lysine-HCL	0.12	0.11	0.01	0.01
Vitamin premix	0.5	0.5	0.5	0.5
Mineral premix	0.5	0.5	0.5	0.5
Coccidiostate	0.05	0.05	0.05	0.05
Total	100	100	100	100
Nutrient compositions calculated				
ME kcal/kg	3010	3010	3175	3175
Crude protein %	22	22	21	21
Calcium %	0.95	0.95	0.90	0.90
Available P. %	0.50	0.50	0.48	0.48
Crude fiber	3.85	3.55	3.41	3.22
Sodium %	0.17	0.17	0.16	0.16
Lysine %	1.36	1.36	1.30	1.30
Met. %	0.61	0.61	0.52	0.52
Met. + Cys. %	0.98	0.98	0.94	0.94
Threonine %	0.90	0.92	0.86	0.87
Tryptophan %	0.49	0.52	0.27	0.27

Table 2 Fatty acid composition (mg/g sample) of experimental diets and fat sources

Fatty acid composition	Starter diets (0-21 d)		Finisher diets (22-42 d)		Fat source	
Fatty acid	SFO	T	SFO	T	SFO	T
Myristic	-	0.69	0.10	0.74	-	-
Palmitic	88	218	76	227	68.34	282.3
Stearic	46	161	42	154	22.13	227.2
Total saturated fatty acids	134	380	118	382	90.47	509.5
Palmitoleic	3	27	2	29	1.04	24.2
Oleic	282	363	268	371	239	289.7
Total monounsaturated fatty acids	285	390	270	400	240.04	314
Linoleic	557	188	584	175	597.40	30.89
Linolenic	2.85	2.92	3.18	3.21	3.22	0
Arachidonic	12	11	13	9	6.52	0
Total polyunsaturated fatty acids	572	202	600	187	507.14	31

SFO: sunflower oil and T: tallow.

At 42 days of age, two birds were randomly selected from each cage and were weighed individually, slaughtered and plucked.

Following chilling of the carcass in cold water, the heads and legs were cut off and the birds were dissected and the internal organs separated. After dressing, abdominal fat, thigh muscles with attached skin and breast meat without skin were dissected and collected.

The samples were frozen and stored at -20 ˚C until further processing. The samples were mixed to obtain a homogenous mixture.

Total lipids from the tissues were extracted with a chloroform-methanol (2:1, vol/vol) mixture according to the method of Folch *et al.* (1957). Then, the extracted fat was saponified with 0.5 *M* methanolic sodium hydroxide and methylated with boronitrifluoride in methanol according to the method of Metcalfe *et al.* (1966). The fatty acid methyl esters obtained were separated and determined by gas chromatography.

Statistical analysis

The general linear model (GLM) of the Statistical Analysis System (SAS, 1996) was used for the statistical processing of data. Differences were considered significant at P<0.05 and means were compared by Duncan test.

RESULTS AND DISCUSSION

The effects of the time of the switch from an unsaturated (SFO) to a saturated (T) dietary fat source on feed intake, body weight gain and feed conversion ratio of broiler chicks in starter (0-21 d), grower (22-42 d) and whole growth periods (0-42 d) of the experiment are shown in Table 3. At 21 days of age, the effect of different dietary treatments on weight gain was not significant. For this stage of growth, feed intake and feed conversion ratio of birds fed mostly the T-based diets were significantly (P<0.05) higher than those fed the SFO-based diets.

For the grower and whole growth periods of the experiment, substitution of T with SFO decreased body weight gain and impaired (P<0.05) feed conversion ratio.

Chicks fed diets supplemented with 5% SFO throughout the entire growth period had the largest body weight gain and best value for feed conversion ratio.

The effects of the source of dietary fat supplementation on carcass fatty acid profile are shown in Tables 4 and 5. There was significant differences between the carcass characteristics due to dietary treatments (P<0.05). Deposition of polyunsaturated fatty acids (PUFAs) was significantly greater in SFO-fed birds compared to those fed diets supplemented with T.

An inverse relationship was found in the content of tissue saturated fatty acids (SFAs) (P<0.05). The predominant fatty acids in the tissues were palmitic (C16:0), oleic (18:0) and linoleic acid for SFA, monounsaturated fatty acid (MUSFA) and PUFA (C18:2), respectively. The highest PUFA / SFA ratio was observed in chicks fed SFO-based diet throughout the entire growth period. The results showed that a substitution of T for SFO during the last week of feeding programs was sufficient to alter the fatty acid composition in the tissues. Similar findings have been previously reported for fat deposition in birds fed diets containing different dietary fat sources (Peebles *et al.* 2000; Calislar and Aydin, 2006; Ghazalah *et al.* 2008).

Trends toward formulation high energy diet makes it necessary for inclusion of fats in broiler feeds. However, the use of unsaturated fat source could negatively affect carcass quality characteristics of broiler chickens due to the excessively low melting point of the deposited fat. In contrast, fats from animal origin, such as T, could lead to an improvement in carcass quality of broiler chickens with respect to physical and sensorial characteristics (Hrdinkab *et al.* 1996).

It was reported that fat metabolism and deposition in poultry could be affected by different dietary fats (Sanz *et al.* 2000).

Table 3 Effects of dietary treatments on body weight, feed intake and feed conversion ratio of broiler chicks during the experimental periods

Growth periods (d)	Dietary treatments[1]							
	6 SFO	5 SFO + 1 T	4 SFO + 2 T	3 SFO + 3 T	2 SFO + 4 T	1 SFO + 5 T	6 T	SEM[4]
Body weight gain (g)[3]								
0-21	413	421	431	443	433	435	446.3	4.41
22-42	1701^{a}	1672^{a}	1675^{a}	1640^{ab}	1557^{bc}	1553^{bc}	1535^{c}	25.98
0-42	2114^{a}	2093^{a}	2100^{a}	2083^{ab}	1990^{b}	1988^{b}	1982^{b}	22.68
Feed intake (g)[3]								
0-21	691^{d}	747^{cd}	781^{bc}	875^{a}	838^{ab}	858^{a}	843^{ab}	25.44
22-42	2892	2907	2945	2943	3097	3043	3117	34.88
0-42	3583^{b}	3653^{b}	3725^{ab}	3817^{ab}	3918^{a}	3901^{a}	3959^{a}	54.28
Feed conversion ratio[3]								
0-21	1.68^{c}	1.77^{bc}	1.81^{abc}	2.00^{a}	1.93^{ab}	1.98^{a}	1.89^{ab}	0.044
22-42	1.71^{c}	1.74^{c}	1.76^{c}	1.79^{bc}	1.98^{ab}	1.96^{ab}	2.04^{a}	0.051
0-42	1.70^{c}	1.75^{c}	1.78^{c}	1.83^{bc}	1.97^{bc}	1.96^{ab}	2.00^{a}	0.045

[1] SFO: sunflower oil and T: tallow.
[2] Number of weeks in which the chicks had free access to SFO or T-based diets. For example, 5 SFO + 1 T stand for 5 weeks SFO-based diet followed by 1 week T-based diet, and so on.
[3] The means within the same row with at least one common letter, do not have significant difference (P>0.05).
[4] SEM: standard error of the means.

Table 4 Saturated and monounsaturated fatty acids composition of tissue lipids of the chicks fed different dietary treatments during the experimental period (0-42 d)

Treatment[1]	Saturated fatty acids				Monounsaturated fatty acids		
	C 14:0	C 16:0	C18:0	Total	C 16:1	C18:1	Total
Abdominal fat[3]							
6 SFO	9.50^{c}	195.73^{b}	55.63^{b}	224.85^{a}	14.55^{e}	*309.92*^{d}	324.46^{e}
5 SFO + 1 T[2]	9.75^{c}	159.99^{b}	57.77^{b}	227.51^{b}	18.32^{de}	312.45^{d}	330.77^{de}
4 SFO + 2 T	10.62^{c}	168.34^{b}	59.34^{b}	238.30^{b}	22.54^{cd}	334.57^{cd}	357.11^{cde}
3 SFO + 3 T	18.31^{b}	178.61^{b}	60.52^{b}	257.44^{b}	23.11^{cd}	365.42^{bcd}	388.54^{cde}
2 SFO + 4 T	18.98^{b}	179.13^{b}	60.55^{b}	258.65^{b}	26.94^{bc}	377.08^{bc}	404.02^{bc}
1 SFO + 5 T	21.31^{b}	181.06^{b}	63.04^{b}	265.41^{b}	32.45^{b}	406.32^{b}	438.77^{b}
6 T	29.03^{a}	224.13^{a}	80.18^{a}	333.35^{b}	39.29^{a}	461.51^{a}	500.81^{a}
SEM[4]	2.08	5.98	2.33	10.53	3.09	15.59	17.96
Thigh muscles[3]							
6 SFO	6.31^{e}	136.38^{b}	40.59^{c}	176.96^{b}	15.09^{d}	354.27^{e}	369.36^{e}
5 SFO + 1 T[2]	6.52^{e}	137.53^{b}	41.25^{c}	178.78^{b}	17.27^{d}	364.94^{de}	383.64^{de}
4 SFO + 2 T	7.36^{e}	138.10^{b}	41.43^{c}	179.53^{b}	18.70^{d}	386.94^{d}	404.21^{d}
3 SFO + 3 T	10.25^{d}	148.19^{b}	41.59^{c}	189.78^{b}	24.73^{c}	413.67^{c}	446.50^{c}
2 SFO + 4 T	15.05^{c}	155.23^{b}	45.28^{c}	200.51^{b}	29.36^{bc}	430.33^{bc}	459.70^{bc}
1 SFO + 5 T	17.18^{b}	185.14^{a}	50.43^{b}	235.56^{a}	32.83^{ab}	453.67^{b}	478.39^{b}
6 T	19.40^{a}	195.19^{a}	59.00^{a}	254.19^{a}	36.99^{a}	480.33^{a}	517.33^{a}
SEM[4]	1.55	6.89	1.95	8.78	2.39	13.26	15.33
Breast muscles[3]							
6 SFO	6.55^{d}	148.73^{d}	43.91^{b}	199.19^{e}	15.95^{e}	364.28^{d}	380.23^{d}
5 SFO + 1 T [2]	8.25^{cd}	150.66^{d}	44.68^{b}	203.59^{e}	18.92^{de}	373.25^{d}	392.17^{d}
4 SFO + 2 T	10.35^{c}	152.67^{d}	47.91^{b}	210.94^{de}	20.59^{de}	419.92^{c}	440.17^{c}
3 SFO + 3 T	13.94^{b}	161.94^{cd}	48.25^{b}	224.12^{cd}	23.58^{cd}	411.18^{bc}	463.76^{c}
2 SFO + 4 T	14.24^{b}	172.13^{c}	49.91^{b}	236.28^{c}	27.94^{bc}	462.39^{b}	490.34^{b}
1 SFO + 5 T	16.83^{b}	187.54^{b}	50.25^{b}	254.62^{b}	32.49^{b}	463.32^{b}	495.81^{b}
6 T	20.03^{a}	222.55^{a}	60.18^{a}	302.76^{a}	39.62^{a}	491.53^{a}	531.15^{a}
SEM[4]	1.37	7.61	1.53	10.38	0.34	13.73	15.88

[1] SFO: sunflower oil and T: tallow.
[2] Number of weeks in which the chicks had free access to SFO or T-based diets. For example, 5 SFO + 1 T stand for 5 weeks SFO-based diet followed by 1 week T-based diet, and so on.
[3] The means within the same row with at least one common letter, do not have significant difference (P>0.05).
[4] SEM: standard error of the means.

The results from this study demonstrated significant effects at the time of the switch from an unsaturated (SFO) to a saturated (T) dietary fat source on body weight gain and feed conversion ratio in grower (22-42 d) and whole growth periods (7-42 d) of the experiment (P<0.05). The poorest feed conversion ratio due to the higher feed intake, and the

Table 5 Polyunsaturated fatty acids composition and their relative proportion in tissue lipids of the chicks fed different dietary treatments during the experimental period (0-42 d)

Treatment[1]	polyunsaturated fatty acids				Relative proportions of fatty acids			
	C 18:2	C 18:3	C20:4	Total	UFA	PUFA:UFA	MUFA:UFA	SFA:UFA
Abdominal fat[3]								
6 SFO	379.55^{a}	6.67^{e}	4.20^{a}	390.41^{a}	714.88^{a}	0.54^{a}	0.45^{e}	0.32^{c}
5 SFO + 1 T[2]	247.56^{b}	7.06^{d}	3.29^{b}	257.91^{b}	588.68^{b}	0.44^{b}	0.56^{d}	0.39^{bc}
4 SFO + 2 T	240.68b^{c}	7.23^{d}	2.76^{b}	250.68^{bc}	607.79^{b}	0.41^{b}	0.59^{d}	0.40^{bc}
3 SFO + 3 T	196.23^{c}	7.98^{c}	2.67^{b}	206.88^{c}	595.42^{b}	0.35^{c}	0.65^{c}	0.43^{b}
2 SFO + 4 T	197.06^{c}	8.03^{c}	1.65^{c}	206.74^{c}	610.76^{b}	0.34^{c}	0.66^{c}	0.43^{b}
1 SFO + 5 T	143.98^{d}	8.37^{b}	1.49^{c}	153.84^{d}	592.61^{b}	0.27^{d}	0.74^{b}	0.45^{b}
6 T	61.43^{e}	8.72^{a}	0.70^{d}	70.83^{e}	571.63^{b}	0.12^{e}	0.88^{a}	0.59^{a}
SEM[4]	28.06	0.214	0.340	28.19	13.52	0.038	0.039	0.023
Thigh muscles[3]								
6 SFO	397.83^{a}	5.28^{c}	4.93^{a}	408.05^{a}	777.41^{a}	0.53^{a}	0.47^{e}	0.23^{b}
5 SFO + 1 T[2]	373.08^{a}	5.59^{c}	4.44^{a}	383.11^{a}	765.32^{ab}	0.50^{a}	0.50^{e}	0.24^{b}
4 SFO + 2 T	339.75^{b}	5.793^{bc}	3.95^{ab}	349.48^{b}	755.12^{ab}	0.46^{b}	0.54^{d}	0.24^{b}
3 SFO + 3 T	302.49^{c}	6.22^{bc}	3.83^{ab}	312.54^{c}	750.94^{ab}	0.42^{c}	0.58^{c}	0.25^{b}
2 SFO + 4 T	295.58^{c}	6.82^{b}	3.85^{ab}	306.25^{c}	765.94^{ab}	0.40^{c}	0.601^{c}	0.26^{b}
1 SFO + 5 T	242.67^{d}	8.24^{b}	2.82^{bc}	253.73^{d}	740.22^{ab}	0.34^{d}	0.67^{b}	0.32^{a}
6 T	189.36^{e}	9.15^{a}	1.63^{c}	200.14^{e}	717.46^{b}	0.28^{e}	0.72^{a}	0.35^{a}
SEM[4]	20.80	0.415	0.313	20.70	5.65	0.025	0.026	0.013
Breast muscles[3]								
6 SFO	393.54^{a}	6.28^{d}	4.82^{a}	404.64^{a}	784.88^{a}	0.51^{a}	0.49^{e}	0.25^{e}
5 SFO + 1 T[2]	369.48^{a}	6.39^{d}	4.79^{a}	380.66^{a}	772.82^{a}	0.49^{a}	0.51^{e}	0.26^{de}
4 SFO + 2 T	322.57^{b}	7.40^{c}	3.81^{b}	333.78^{b}	774.29^{a}	0.43^{b}	0.57^{d}	0.27^{de}
3 SFO + 3 T	290.88^{c}	7.64^{c}	3.37^{bc}	301.89^{c}	765.65^{a}	0.39^{c}	0.61^{c}	0.29^{cd}
2 SFO + 4 T	240.21^{d}	8.00^{bc}	2.73^{cd}	250.94^{d}	741.27^{b}	0.34^{d}	0.66^{b}	0.32^{c}
1 SFO + 5 T	216.91^{d}	8.45^{b}	2.08^{d}	227.44^{d}	723.25^{b}	0.32^{d}	0.68^{b}	0.35^{b}
6 T	112.90^{e}	9.61^{a}	0.84^{e}	123.35^{e}	654.51^{c}	0.19^{e}	0.81^{a}	0.46^{a}
SEM[4]	27.67	0.332	0.414	27.75	12.95	0.031	0.031	0.021

[1] SFO: sunflower oil and T: tallow.

[2] Number of weeks in which the chicks had free access to SFO or T-based diets. For example, 5 SFO + 1 T stand for 5 weeks SFO-based diet followed by 1 week T-based diet, and so on.

[3] The means within the same row with at least one common letter, do not have significant difference (P>0.05).

[4] SEM: standard error of the means.

lower weight gain was seen in chicks fed T-based diet for the entire growth period, which was in agreement with the results reported by other researchers (Crespo and Esteve-Garcia, 2001; Villaverde *et al.* 2006; Ferrini *et al.* 2008). These effects may reflect actual differences in metabolizable energy content among the experimental diets due to differences in dietary fat digestibility. Oils form plant origins contain high levels of UFAs and are more completely digested by fowl than animal fats (Wiseman and Salvador, 1991; Leeson and Atteh, 1995). At 21 days of age, the lack of differences between dietary treatments for body weight gain is consistent with the observation of Leeason and Atteh (1995) and Pesti *et al.* (2002).

CONCLUSION

The use of unsaturated dietary fats decreases the melting point of the fat in the broiler carcass (Bavelaar and Beynen, 2003), diminishing the firmness of the fat (Glaser, 2004) and causing technological incidents in slaughter houses due to the oily fat problem. Therefore, when fat supplementation is performed in broiler diets the effects on carcass fat quality must be taken into account. As can be seen from the results of this study (Tables 4 and 5), shifting from SFO to T just for a few weeks time was capable in altering the profile of fatty acids toward a more saturated pattern. However, an increase in the SFAs at expense of PUFAs may increase the risk of coronary arterial disease. Therefore, caution is needed in choosing the best time of the switch from an unsaturated to a saturated dietary fat source.

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