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≪Research Note≫

Deposition of Dietary Bioactive Fatty Acids in Tissues of Broiler Chickens

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This study examined the deposition of dietary bioactive fatty acids (FAs), including medium-chain and essential FAs, in tissues of broiler chickens. Six hundred newly hatched chicks were allotted to 4 treatments, 6 replicates of 25 chicks per treatment. The chicks were fed diets containing 0%, 1.6%, 4.0%, or 6.4% medium-chain triglycerides (MCTs) for 36 d. The abdominal fat deposition, fat content, and FA composition of breast meat, thigh meat, and abdominal fat were measured. The accumulation rate (AR) of bioactive FAs in the tissues was estimated as the slope of the linear regression between the FA composition of tissues and diets. Results showed that a diet containing 6.4% MCTs reduced the abdominal fat deposition and fat content of thigh meat ($P<0.05$). Essential FAs had higher AR than did medium-chain FAs. The AR of C10:0 was higher than that of C8:0. Moreover, C6:0 could not be detected in the tissues of broiler chickens. In conclusion, essential, but not medium-chain, FAs could efficiently deposit in tissues of broiler chickens.

Key words: chicken meat, deposition, essential fatty acids, medium-chain fatty acids

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Introduction

In addition to the energy-yielding property, bioactive fatty acids (FAs), such as medium-chain FAs (MCFAs; FAs having 6 to 12 carbon atoms) and essential FAs [EFAs; including linoleic (C18:2) and α-linolenic (C18:3) acids], provide health benifits to humans and animals (Aluko, 2012).

The antiobesity effect of MCFAs in humans has been one of the most commonly reported special biological functions. MCFAs could increase energy expenditure (Seaton *et al*., 1986; Hill *et al*., 1989; Scalfi *et al*., 1991; Papamandjaris *et al*., 2000) and decrease the body fat content of humans (St-Onge and Jones, 2002, 2003; St-Onge and Bosarge, 2008), particularly those of overweight individuals (Tsuji *et al*., 2001; St-Onge and Bosarge, 2008). The antiobesity effect of MCFAs was also demonstrated in rats (Lavau and Hashim, 1978; Baba *et al*., 1982; Takeuchi *et al*., 2006; Terada *et al*., 2012), pigs (Newport *et al*., 1979), and broiler chickens (Chiang *et al*., 1990; Mabayo *et al*., 1993).

By contrast, the antidiabetic effect of MCFAs has been less reported. Several studies have reported that MCFAs improved the insulin sensitivity of overweight patients with type II diabetes (Han *et al*., 2007) and the insulin sensitivity and glucose tolerance of rats (Han *et al*., 2003; Wein *et al*., 2009).

The dietary essentiality of EFAs have been known for decades (Burr and Burr, 1969). Long-chain FAs (LCFAs), including EFAs, in diets was found could be easily deposited in the body of chickens, with minor modifications (Crespo and Esteve-Garcia, 2001; Smink *et al*., 2010). Therefore, the LCFA profile of the body clearly correlated with the dietary LCFA profile. The efficiency of deposition of EFAs was high in the body of broiler chickens (Villaverde *et al*., 2006; Smink *et al*., 2010).

Because MCFAs are predominantly oxidized for energy production in animals (Bach and Babayan, 1982; Chiang *et al*., 1990), they may be deposited less in the body of animals. Studies on rats (Kinkela *et al*., 1983; Hill *et al*., 1993) and human infants (Sarda *et al*., 1987) have indicated that the efficiency of deposition of MCFAs in subcutaneous fat was low. No studies have been conducted on the deposition of MCFAs in the body of chickens. The knowledge of the deposition of bioactive FAs in the body of chickens could be useful for producing chicken meat having health benefits for humans.

Therefore, this study was designed to investigate the effect of dietary MCFAs supplementation on fatty acid composition and their accumulation rate (AR) in the breast and thigh meat and the abdominal fat of broiler chickens.

Materials and Methods

Birds, Diets, and Experimental Design

All procedures concerning animal care and use were approved by the Tunghai University Animal Care and Use

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Committee.

Six hundred 1-d-old mixed-sex Arbor Acres broiler chicks were randomly allotted to 4 treatments, 6 replicates for each treatment, and 25 chicks per replicate. Chicks were fed isonitrogenous and isocaloric corn-soybean meal diets containing 0%, 1.6%, 4.0%, and 6.4% medium-chain triglycerides (MCTs). Chicks received a starter diet (containing 22.5 % crude protein and 3,200 kcal/kg metabolizable energy) until Day 18 and a finisher diet (containing 19.9% crude protein and 3,250 kcal/kg metabolizable energy) between Days 19 and 36. The total FA content and its composition in the starter and finisher diets are shown in Table 1. The diets were in a mash form and provided *ad libitum*, and the chicks had free access to tap water.

The chicks were reared in floor pens (108 cm×51 cm) bedded with rice hulls. The pens were illuminated at nighttime. Electric intrared heat lamps were used to keep chicks warm and comfortable.

Sample Preparation and Measurements

The body weight and feed intake were measured at the beginning and on Days 18 and 36 of the experiment. At the end of the experiment, 2 birds close to average body weight were chosen from each pen and sacrificed through CO_2 asphyxiation (n=12). The breast meat without skin, thigh meat with skin, and abdominal fat were collected and weighed. The tissue samples were placed into ice-cold water immediately. The cooled samples were homogenized using a blender (7010G/51BL30, Waring Commercial Co.), and the homogenates were stored at −20℃.

The frozen homogenates were thawed and their total fat contents were measured using the method proposed by Folch *et al*. (1957). The fat was extracted using chloroform–methanol (2:1) solvent, the solvent was evaporated by flowing nitrogen gas, and the dried total fat content was measured gravimetrically. The FA composition of the diets and homogenates was measured using the method of Sukhija and Palmquist (1988). In brief, FAs were transmethylated to FA

Table 1. **Fatty acid content and its composition in starter and finisher diets**

Item	Dietary MCT, %			
	0	1.6	4.0	6.4
Starter diet				
Total fatty acid (TFA), g/100 g	9.81	9.74	9.73	9.60
g/100 g of TFA				
C6:0	0.00	4.41	10.39	16.66
C8:0	0.00	6.53	15.36	24.73
C10:0	0.00	3.64	8.43	13.67
C16:0	13.27	11.60	9.71	7.30
C18:0	5.75	4.89	4.03	2.99
C18:1	22.49	19.13	14.53	9.77
C18:2	51.93	44.45	33.53	22.16
C18:3	6.56	5.35	4.02	2.72
MCFA[1]	0.00	14.58	34.18	55.06
LCFA[2]	100.00	85.42	65.82	44.94
LCSFA[3]	19.02	16.49	13.74	10.29
LCUSFA[4]	80.98	68.93	52.08	34.65
Finisher diet				
Total fatty acid (TFA), g/100 g	9.89	10.64	11.07	9.26
g/100 g of TFA				
C6:0	0.00	4.44	11.05	15.60
C8:0	0.00	6.35	15.75	23.69
C10:0	0.00	3.59	8.17	13.52
C16:0	13.51	11.71	9.44	7.57
C18:0	6.08	4.91	3.91	3.09
C18:1	19.49	18.96	14.40	10.23
C18:2	53.93	44.60	33.24	23.54
C18:3	6.99	5.44	4.04	2.76
MCFA[1]	0.00	14.38	34.97	52.81
LCFA[2]	100.00	85.62	65.03	47.19
LCSFA[3]	19.59	16.62	13.35	10.66
LCUSFA[4]	80.41	69.00	51.68	36.53

[1] Medium-chain fatty acids.
[2] Long-chain fatty acids.
[3] Long-chain saturated fatty acids.
[4] Long-chain unsaturated fatty acids.

methyl esters (FAMEs), and the FAMEs composition was measured using gas chromatography with a flame ionization detector (FID, Model G-3000, Hitachi, Tokyo, Japan) and a 30 m×0.25 mm SP-2330 fused silica capillary column (Supelco Inc., Bellefonte, PA, USA). The oven, injector and FID detector temperatures were 40, 250 and 250℃, respectively. The flow rates of hydrogen, nitrogen, and air were 20, 20, and 2.5 mL/min, respectively. FAMEs peaks were routinely identified by comparison of retention times with FAMEs standards (Sigma-Aldrich, MO, USA). The peak areas were calculated as the composition of corresponded FAMEs.

Calculations and Statistical Analyses

The AR of FAs in the tissues was estimated as the slope of the linear regression between the FA composition of tissues and diets. The tissue FA composition was used as a dependent variable and the dietary FA composition was used as an independent variable. Regression analyses were performed by following the REG procedure of SAS (SAS, 2000). Data from each pen were used as an experimental unit. The effects of dietary treatment were analyzed using a completely randomized design by the GLM procedures of SAS (SAS, 2000). The statistical significant differences among the treatments was assessed using a Tukey's Honestly Significant Difference test. A probability level of $P<0.05$ was considered to be statistically significant.

Results and Discussion

The body weight gain and feed conversion rate of chicks fed diets supplemented with various levels of MCTs remained unchanged (data not shown).

The dietary supplementation of MCTs did not affect the total fat content of breast meat (Table 2). Conversely, the dietary supplementation of MCTs at the level of 6.4% reduced not only the total fat content of thigh meat ($P<0.05$) but also the abdominal fat weight ($P<0.01$) (Table 2). The MCFAs-induced effect on adipose tissue accretion was consistent with the findings observed in chickens (Chiang *et al*., 1990; Mabayo *et al*., 1993), rats (Lavau and Hashim, 1978; Baba *et al*., 1982; Takeuchi *et al*., 2006; Terada *et al*., 2012), pigs (Newport *et al*., 1979), and humans (Tsuji *et al*., 2001; St-Onge and Jones, 2002, 2003; St-Onge and Bosarge, 2008). MCFAs may stimulate lipolysis in adipose tissues (Shinohara *et al*., 2006) and increase thermogenesis (Baba et al., 1982), resulting in the adipose tissue accretion reduction.

Although MCT source contained C6:0, C8:0, and C10:0, C6:0 was not detectable in the breast meat and thigh meat, with minimal amount found in the abdominal fat in the highest level of MCT (Table 2). Conversely, the contents of C8:0 and C10:0 in the breast meat, thigh meat, and abdominal fat (Table 2) increased when the supplemented levels of MCT rose ($P<0.05$). These results indicate that the deposition of MCFAs is dependent on its carbon chain length. It was reported that the longer the carbon chain of MCFA, the easier that it could deposit in the body (Sarda *et al*., 1987). Our results are consistent with these findings.

The contents of EFAs and LCFAs shown in breast meat, thigh meat, and abdominal fat (Table 2), decreased when the supplemented level of MCTs increased ($P<0.05$). Replacing soybean oil that reduced the dietary EFA and LCFAs contents reduced the EFA and LCFAs contents in these tissues. These findings are consistent with the findings that the LCFAs profile of the body correlates with the dietary LCFAs profile (Crespo and Esteve-Garcia, 2001; Smink *et al*., 2010).

However, the contents of nonessential fatty acids (NEFAs) in the breast meat, thigh meat, and abdominal fat (Table 2) increased as the dietary MCTs increased ($P<0.05$). Replacing soybean oil with MCTs in MCT-containing diets reduced the dietary NEFAs content but increased the NEFAs contents in the body. These findings suggested that MCFAs increase the net de novo synthesis of NEFAs and stimulate their synthesis. Dietary MCFAs increased the deposition of NEFAs in the abdominal fat of rats (Tucci *et al*., 2011). Bach and Babayan (1982) indicated that MCFAs could easily be converted to acetyl-CoA, the precursor of FA synthesis, in the liver of rats. Therefore, increasing dietary MCTs may provide more acetyl-CoA and hence increase the C16:0 synthesis. By increasing the C16:0 synthesis, the synthesis of other NEFAs, such as C18:0, C16:1, and C18:1, could be increased through the elongation and desaturation processes. Furthermore, polyunsaturated FAs could inhibit the Δ9 desaturase activity (Kouba and Mourot, 1998). Therefore, the lower polyunsaturated FA content in MCT-containing diets may stimulate the desaturation of C16:0, and hence, the synthesis of C16:1 and C18:1. Such a relationship between polyunsaturated FAs and desaturation was clearly illustrated in broiler chickens in the studies reported by Infield and Annison (1973) and Smink *et al*. (2010).

The MCFAs and EFAs accumulated in the bodies of animals are exclusively of a dietary origin. This is because MCFAs are not the end products of de novo lipogenesis, and EFAs cannot be synthesized by animals (Bartov, 1979; Crespo and Esteve-Garcia, 2002). Therefore, the slopes of the regression between tissue and dietary MCFAs and EFAs may represent the AR of these FAs in the tissues. Except that the AR of C18:2 is lower in the breast meat (i.e., 0.46), that of C18:2 and C18:3 in the thigh meat and abdominal fat (Table 3) is comparable with the values of 0.7 and 0.5, respectively (Villaverde *et al*., 2006; Smink *et al*., 2010). We found that the AR of MCFAs was less than 0.5 in the breast meat, thigh meat and abdominal fat. (Table 3). The AR of MCFAs was found less than 0.12 in the subcutaneous fat of human infants (Sarda *et al*., 1987). These findings clearly indicated the high AR of EFAs over MCFAs in the bodies of animals.

In conclusion, MCFAs could be enriched in the chicken meat although the AR was much lower than that of EFAs. However, until a detailed strategy, including the dosage, duration and chain length of MCFAs for evoking human health benefits is known, the significance of the enrichment of MCFAs in chicken meat remain uncertain.

Table 2. **Effect of various levels of medium chain triglycerides in the diet on the total fat content and fatty acid composition of breast meat (without skin), thigh meat (with skin) and abdominal fat**

Dietary MCT, %	0	1.6	4.0	6.4	SEM	*P*-value
			Breast meat (without skin)			
Total fat content, g/100 g	1.82	1.91	1.81	1.73	0.07	0.37
Fatty acid, g/100 g of total fatty acids						
C6:0	0.00	0.00	0.00	0.00	—	—
C8:0	0.00^{c}	0.92^{b}	1.43^{a}	1.47^{a}	0.08	<0.01
C10:0	0.00^{d}	0.94^{c}	2.34^{b}	3.24^{a}	0.13	<0.01
C16:0	25.74^{b}	25.02^{b}	26.45^{b}	30.21^{a}	0.54	<0.01
C16:1	1.07^{c}	1.59^{bc}	2.01^{ab}	2.87^{a}	0.22	<0.01
C18:0	14.41^{ab}	13.82^{b}	14.83^{ab}	16.35^{a}	0.49	0.02
C18:1	21.00^{b}	22.55^{ab}	23.24^{a}	23.62^{a}	0.51	0.01
C18:2	34.75^{a}	32.37^{a}	27.53^{b}	20.84^{c}	0.65	<0.01
C18:3	3.04^{a}	2.80^{a}	2.18^{b}	1.40^{c}	0.06	<0.01
MCFA[1]	0.00^{d}	1.86^{c}	3.76^{b}	4.72^{a}	0.20	<0.01
LCFA[2]	100.00^{a}	98.14^{b}	96.24^{c}	95.28^{d}	0.20	<0.01
LCSFA[3]	40.15^{b}	39.57^{b}	42.89^{b}	48.85^{a}	0.92	<0.01
LCUSFA[4]	59.85^{a}	60.43^{a}	57.11^{a}	51.15^{b}	0.92	<0.01
			Thigh meat (with skin)			
Total fat content, g/100 g	14.70^{a}	14.06^{ab}	13.72^{ab}	11.95^{b}	0.64	<0.05
Fatty acid, g/100 g of total fatty acids						
C6:0	0.00	0.00	0.00	0.00	—	—
C8:0	0.00^{d}	0.86^{c}	1.83^{b}	2.53^{a}	0.07	<0.01
C10:0	0.00^{d}	1.34^{c}	3.63^{b}	5.91^{a}	0.12	<0.01
C16:0	15.61^{c}	16.88^{c}	18.90^{b}	21.42^{a}	0.33	<0.01
C16:1	3.66^{c}	3.95^{c}	4.75^{b}	6.54^{a}	0.18	<0.01
C18:0	5.56^{b}	6.14^{ab}	6.78^{a}	6.79^{a}	0.19	<0.01
C18:1	26.74^{c}	27.49^{bc}	29.02^{b}	30.67^{a}	0.39	<0.01
C18:2	45.63^{a}	40.32^{b}	33.19^{c}	24.87^{d}	0.66	<0.01
C18:3	2.80^{ab}	3.02^{a}	1.90^{bc}	1.27^{c}	0.24	<0.01
MCFA[1]	0.00^{d}	2.21^{c}	5.45^{b}	8.45^{a}	0.18	<0.01
LCFA[2]	100.00^{a}	97.79^{b}	94.55^{c}	91.55^{d}	0.18	<0.01
LCSFA[3]	21.17^{d}	23.54^{c}	27.16^{b}	30.81^{a}	0.41	<0.01
LCUSFA[4]	78.83^{a}	76.46^{b}	72.84^{c}	69.19^{d}	0.14	<0.01
			Abdominal fat			
AF[5], g/100 g	1.33^{a}	1.22^{a}	1.16^{ab}	0.96^{b}	0.07	<0.01
Fatty acid, g/100 g of total fatty acids						
C6:0	0.00	0.00	0.00	0.04	0.02	0.42
C8:0	0.00^{b}	0.00^{b}	2.08^{a}	1.72^{a}	0.12	<0.01
C10:0	0.00^{c}	0.00^{c}	3.28^{b}	5.37^{a}	0.25	<0.01
C16:0	20.73	20.38	21.30	23.35	0.76	0.06
C16:1	2.70^{b}	3.35^{b}	3.20^{b}	5.22^{a}	0.30	<0.01
C18:0	4.89^{b}	5.64^{ab}	6.25^{a}	6.38^{a}	0.20	<0.01
C18:1	27.94^{c}	30.36^{b}	31.68^{b}	34.81^{a}	0.48	<0.01
C18:2	40.55^{a}	37.41^{b}	29.02^{c}	21.09^{d}	0.56	<0.01
C18:3	3.19^{a}	2.86^{a}	2.41^{a}	1.40^{b}	0.21	<0.01
MCFA[1]	0.00^{c}	0.00^{c}	5.35^{b}	7.14^{a}	0.24	<0.01
LCFA[2]	100.00^{a}	100.00^{a}	94.65^{b}	92.86^{c}	0.24	<0.01
LCSFA[3]	25.62^{c}	26.03^{c}	29.95^{b}	32.67^{a}	0.64	<0.01
LCUSFA[4]	74.38^{a}	73.97^{a}	70.05^{b}	67.33^{c}	0.64	<0.01

[1] Medium-chain fatty acids.
[2] Long-chain fatty acids.
[3] Long-chain saturated fatty acids.
[4] Long-chain unsaturated fatty acids.
[5] Abdominal fat weight/body weight, g/100 g.
[a, b, c, d] Values within each row with different superscripts are significantly different ($P<0.05$).

Table 3. **Regression between tissue and dietary fatty acid composition**

Fatty acid	Intercept	Slope	SEM	r^2	*P*-value
Breast meat					
C6:0	0.00	0.00	—	—	—
C8:0	0.29	0.06	0.64	0.74	<0.01
C10:0	0.15	0.25	0.74	0.92	<0.01
C16:0	3.39	−0.79	3.91	0.43	<0.01
C18:0	1.41	−0.76	3.01	0.20	0.03
C18:1	2.82	−0.23	2.94	0.24	0.02
C18:2	1.06	0.46	3.89	0.88	<0.01
C18:3	0.14	0.43	0.44	0.89	<0.01
Thigh meat					
C6:0	0.00	0.00	—	—	—
C8:0	0.12	0.11	0.36	0.97	<0.01
C10:0	0.02	0.46	0.52	0.99	<0.01
C16:0	5.53	−1.02	1.42	0.90	<0.01
C18:0	1.40	−0.50	0.99	0.50	<0.01
C18:1	3.93	−0.41	1.94	0.70	<0.01
C18:2	0.75	0.68	3.54	0.95	<0.01
C18:3	0.12	0.44	1.21	0.54	<0.01
Abdominal fat					
C6:0	−0.01	0.00	0.10	0.08	0.19
C8:0	−0.09	0.09	1.11	0.69	<0.01
C10:0	−0.51	0.45	1.65	0.88	<0.01
C16:0	2.05	−0.47	4.75	0.15	0.06
C18:0	1.65	−0.58	1.03	0.55	<0.01
C18:1	6.71	−0.64	3.47	0.64	<0.01
C18:2	0.90	0.66	3.48	0.95	<0.01
C18:3	0.21	0.45	0.96	0.65	<0.01

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