Lipid deposition and fatty acid composition of some adipose depots in lambs fed coconut oil supplemented diet

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SUMMARY

A study with 10 male lambs of Bulgarian dairy synthetic population was carried out to investigate the effect of dietary coconut oil supplementation on the lipid deposition of the carcass and the fatty acid composition in the internal, subcutaneous and intermuscular adipose tissue. The animals were divided in two groups - control and experimental, as the lambs from the latter received diet supplemented with coconut oil in amount 20g /d per animal for a period of three months.

Judged by the measurements of the thickness of the subcutaneous adipose tissue in three locations, the dietary coconut oil supplementation did not increase significantly the lipid deposition of the carcass. Although a trend towards higher thickness of the subcutaneous fat in these locations was observed in the animals from the coconut oil supplemented group. Adipose tissue deposition was dependent on the location in the carcass.

The content of the lauric, myristic and palmitic fatty acids, the total amount of the saturated fatty acids and the values of the atherogenic index were significantly increased ($P<0.001$) in response to the coconut oil included in the diet, thus indicating a certain unfavourable effect of the dietary coconut oil supplementation in amount of 20 g/d per animal.

The content of the stearic acid as well as the stearoyl-CoA desaturase and elongase activities, and the total amount of the polyunsaturated fatty acids were lower ($P<0.001$; $P<0.01$) in the animals that received coconut oil. For most of the fatty acids depot specific influence was observed.

Keywords: lambs, coconut oil, lipids, fatty acids

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INTRODUCTION

The widely accepted recommendation, concerning human health is to limit the content of the fat, especially saturated fatty acids in the diet. Since meat is considered to be one of the major sources of saturated fatty acids in the human diet attempts are being made to modify the fatty acid composition of the tissues of growing meat producing animals towards more unsaturated fatty acids. This could be achieved by supplementation of various sources of fatty acids in the diet of the animals. In ruminants dietary fat supplementation has been studied in order to improve various physiological processes (Hess et al., 2008). It might prevent ruminal acidosis, facilitate absorption of lipo-soluble nutrients (Perez et al., 2002), improves the energy efficiency by facilitating direct use of long chain fatty acids in the metabolic pathways of fat synthesis in place of acetate and glucose (Clinquart et al., 1995; Machmüller et al., 2000). The sources of saturated fatty acids also have their place in the dietary fat supplementation in ruminants, mainly as a source of energy.

The research on the influence of specific saturated fatty acids in the lipid metabolism of ruminants is relatively limited (Bozzolo et al., 1993; Castro et al., 2005). Coconut oil is rich in lauric acid which although considered unhealthy, is reported to have antibacterial (Hinton et al., 2006, Nakatsuji, 2009) antioxidative and antiviral (Hornung et al., 1994) properties. Studies conducted to assess effects of fat supplementation on the performance and body composition of ruminants have had variable results, which could be due to the level and source of fat, and the nature of the basal diet, which determined effects of this fat on ruminal microbes (Abou Ward et al., 2008).

Hence the aim of this study was to investigate the effect of the coconut oil on the lipid deposition of the carcass and fatty acid composition of various fat depots as an edible part of the meat in growing lambs.

MATERIAL AND METHODS

The study was carried out with 10 male lambs of Bulgarian dairy synthetic population divided in 2 groups (5 animals each). The initial live weight of the animals was 18.04±2.6 kg and 18.12±2.74 kg, respectively for the control and experimental groups. The lambs from the two groups were fed concentrate diet (20 % corn, 30% barley, 50 % soy meal, vitamin premix 0.0013 g per animal) starting at the amount of 0.800 kg per animal per day and it was increased proportionally according to the consumption until reached 1.100 kg per animal per day at the end of the experiment. The hay started at 0.800 kg per animal per day and was fed *ad libitum*. For a period of 3 months each animal of the experimental group additionally received coconut oil in amount

20 g per day. The diet and coconut oil fatty acid composition are presented in Table 1.

Table.1 Fatty acid composition of diet and coconut oil

Fatty acids, %	Coconut oil	Concentrate	Hay
C10:0	7.59	0.49	2.60
C12:0	50.65	0.13	1.65
C14:0	17.9	0.58	4.18
C15:0	-	-	2.71
C16:0	10.47	15.59	26.24
C16:1	-	0.28	1.32
C17:0	-	0.16	0.99
C18:0	3.59	3.55	10.40
C18:1	8.33	22.4	23.97
C18:2	1.47	54.8	11.91
C18:3	-	2.01	14.04

The animals were slaughtered at mean live weight 37.07±4.62 kg for the control and 37.02±4.35kg for the experimental group.

The thickness of the subcutaneous adipose tissue was measured in three locations of the lamb carcasses – above m. *Longissimus dorsi* (at the 11th rib), at *os Sternum* and at the base of the tale. Samples from internal (caul and perirenal fat), subcutaneous (above m. *Longissimus dorsi*, at the 11th rib) and intermuscular (under m. Semimebranosus) fat were taken 24 h after the slaughter.

Total lipids of the four fat depots were extracted according to the method of Bligh and Dyer (1959). Methyl esters of the triacylglycerols, isolated by preparative thin-layer chromatography, were obtained using 0.01% solution of sulphuric acid in dry methanol at 47 °C for 14 h as described by Christie (1973). The fatty acid composition of the triacylglycerols was determined by GLC analysis on chromatograph Carlo Erba, equipped with a capillary column. The output from the flame ionization detector was quantified using a computing integrator (Spectra Physics, 4100).

Data was presented as mean values. Two-way ANOVA was applied to determine the influence of the treatment as well as the location of the adipose tissues in the current study. Statistical evaluation was performed using JMP v.7 (2007).

RESULTS AND DISCUSSION

Lipid deposition in the carcass

There was no significant influence of the coconut oil supplementation on the thickness of the adipose tissue in the different anatomical locations of the carcass (Table 2). Though there were trends towards more subcutaneous fat deposition in the three locations of the measurement in the lambs from the experimental group. Similar results were reported by Bhatt et al., 2011, Dutta et al., 2008, Castro et al, 2005, who showed that the inclusion of saturated fatty acids in the diet (respectively from coconut and palm oil) did not result in significant change of the carcass fatness in lambs. Contrary to our findings, Solomon et al., 1992 found higher content of subcutaneous fat in lambs fed palm oil. The lack of significant influence of the coconut oil supplementation on the lipid deposition is perhaps due to the variation between the animals.

Table.2 Lipid deposition in the lambs in response to coconut oil supplementation

	Location						Significance			
	above m. LD		at os Sternum		at the base of the tail		Location	Diet	Interact.	S.E.
Diet	C[a]	CO[b]	C	CO	C	CO				
Subcutaneous adipose tissue, mm	4.6	5.64	5.06	5.56	7.44	10	***	NS	NS	1.74

[a]Control diet

[b]Coconut oil supplemented diet

*** P<0.001

The measurements of the subcutaneous fat thickness in the pointed locations are important for the classification of the lamb carcasses according to the SEUROP system. The lack of significant difference in this parameter shows that the dietary coconut oil supplementation does not influence significantly the degree of fatness of the lamb carcasses and they will be in the same class according to this parameter.

The degree of fat deposition was specific and depended on the location in the carcass (P<0.001). The lowest is above m. *Longissimus dorsi* and the highest - at the base of the tail. Similar site-specific deposition of the subcutaneous adipose tissue was observed in other experiment with lambs (Popova, 2009).

Besides the quantitative changes of the adipose tissue, coconut oil supplementation might enhance sensory alteration as well. The incorporation of coconut oil in the adipose depots might increase the firmness of the fat due to the increased amounts of saturated fatty acids (Lourenco et al., 2010). The results of other experiments (Busboom et al., 1981) showed that the fat firmness increased with the augmentation of the levels of the capric, myristic , palmitic and stearic acids in the diet of lambs.

Table. 3 Fatty acid composition of fat depots in lambs in response to coconut oil supplementation

Fatty acids, %	Fat depots											
	Subcutaneous		Perirenal		Caul		Intermuscular		Significance			
	Diet											
	C[a]	CO[b]	C	CO	C	CO	C	CO	Diet	Fat depot	Inter-action	S.E.
C10:0	0.79	0.81	0.78	0.51	0.62	0.55	0.61	0.71	NS	NS	NS	0.24
C12:0	1.33	3.35	1.11	3.66	1.56	3.44	1.45	3.14	***	NS	NS	0.98
C14:0	6.68	12.31	6.15	13.27	6.07	12.78	7.60	11.51	***	NS	NS	1.98
C15:0	0.86	1.04	0.93	0.82	0.89	0.80	1.00	0.91	NS	NS	NS	0.2
C16:0	27.03	29.37	22.07	25.48	22.73	25.89	23.73	27.41	***	***	NS	2.01
C16:1	2.46	3.06	1.30	1.75	1.39	1.99	2.36	2.84	***	***	NS	0.32
C17:0	1.32	1.22	1.36	0.95	1.38	0.91	1.17	1.07	***	NS	*	0.18
C18:0	13.05	11.21	24.47	19.52	24.19	18.72	15.38	12.76	***	***	NS	2.91
C18:1	42.17	33.68	34.68	29.11	34.49	29.57	39.29	34.83	***	***	NS	3.03
C18:2	3.33	3.04	5.90	3.96	5.44	4.26	4.97	3.67	***	***	NS	0.84
C18:3	0.32	0.22	0.54	0.33	0.49	0.36	0.50	0.38	***	***	NS	0.07
CLA[c]	0.67	0.68	0.70	0.63	0.74	0.72	0.92	0.77	NS	NS	NS	0.15
SFA[d]	51.05	59.31	56.88	64.21	57.44	63.10	50.94	57.51	***	***	NS	3.13
MUFA[e]	44.63	36.75	35.97	30.86	35.89	31.56	41.65	37.67	***	***	NS	3.07
PUFA[f]	4.32	3.94	7.15	4.93	6.67	5.34	6.40	4.82	***	***	NS	0.86
P:S[g]	0.08	0.07	0.13	0.08	0.12	0.08	0.13	0.08	***	**	NS	0.01
AI[h]	1.14	2.05	1.11	2.35	1.14	2.18	1.17	1.82	***	NS	NS	0.35
SCD index[i]	52.66	47.44	43.59	40.57	41.66	41.45	51.54	48.33	**	***	NS	2.78
Elongase index[j]	0.48	0.39	1.13	0.77	1.11	0.73	0.65	0.47	***	***	NS	0.18

[a] Control
[b] Coconut supplemented diet
[c] Conjugated linoleic acids
[d] Saturated fatty acids
[e] Monounsaturated fatty acids
[f] Polyunsaturated fatty acids
[g] Polyunsaturated: saturated fatty acids
[h] Atherogenic index =[C12:0+(4xC14:0)+C16:0]/(PUFA+MUFA)
[I] Stearoyl CoA desaturase index =100x[(C16:1+C18:1)/(C16:0+C16:1+C18:0+C18:1)]
[j] Elongase index=C18:0/C16:0
** P<0.01; *** P<0.001

Fatty acid composition of adipose depots

Dietary coconut oil supplementation (Table 3) led to significant increase ($P<0.001$) of the lauric acid (C12:0) in the fat depots of the lambs from the experimental group as its amounts doubled those in the animals from the control group. The contents of the myristic and palmitic acids were also influenced by the inclusion of the coconut oil in the diet of the lambs and became significantly higher ($P<0.001$) in the animals from the supplemented group. This is in agreement with our results for the influence of coconut oil supplementation on the fatty acid composition of muscle triacylglycerols (Popova, 2011). The results of our study are in accordance with those of Castro et al., 2005 and Manso et al, 2009 who studied the influence of palm oil, rich in palmitic acid on the fatty acid composition of adipose tissue and found significant increase of this fatty acid in the lipids of the internal fat depots. On the other hand Solomon et al., 1992 reported decrease in the content of myristic acid in the subcutaneous fat in lambs fed palm oil supplemented diet. The three fatty acids C12:0, C14:0 and C16:0 are known to be hyperlipidemic and increase the levels of serum cholesterol (Temme et al., 1997; Grundi, 2006) which is connected to increased risk of coronary heart diseases. A better evaluation of the effects of these fatty acids on the development of coronary heart diseases might be done by the atherogenic index. Its values corresponded to the changes of the three fatty acids and were significantly higher ($P<0.001$) in the lambs from the coconut oil supplemented diet. This suggests certain unfavourable effect of coconut oil supplemented in amounts of 20 g/d per animal in concerns to human health.

Coconut oil supplementation of the diet decreased significantly the content of margaric (C17:0) ($P<0.001$) and stearic (C18:0) ($P<0.001$) fatty acids in the fat depots of lambs from the experimental group. The odd carbon numbered fatty acids are found in relatively big amounts in the adipose tissue of the ruminant animals because of the greater synthesis of these fatty acids from the rumen bacteria (Drakley, 2000). The decreases in the amount of the margaric acid in the fat depots in this study are in agreement with the results reported by us for the changes in the content of this fatty acid in muscle triacylglycerols (Popova, 2011). Solomon et al., 1992 also showed reduced content of margaric acid in subcutaneous and intramuscular fat when feeding lambs with palm oil supplemented diet. This suggests that the elevated amount of saturated fatty acids in the diet of ruminant animals restrains the activity of the ruminal microorganisms.

As a whole the dietary coconut oil supplementation increased significantly ($P<0.001$) the total saturated fatty acid content in the lambs from the experimental group.

The deposition of the saturated fatty acids that we observed was specific for the individual fat depot. The internal fat depots (perirenal fat and caul) had the highest ($P<0.001$) amount of the saturated fatty acids followed by the intermuscular and subcutaneous fat.

The contents of palmitoleic fatty (C16:1) acid was significantly increased ($P<0.001$) and that of the oleic (C18:1) decreased ($P<0.001$) in the fat depots of the lambs fed coconut oil supplemented diet.

The content of the linoleic (C18:2) and linolenic (C18:3) acids were decreased as well ($P<0.001$). This is in agreement with the results of Solomon et al., 1992 and Castro et al., 2005 who reported decreased content of the linoleic and linolenic fatty acid in the fat tissue of palm oil fed lambs.

The changes observed led to significant decrease of the total amount of mono- and polyunsaturated fatty acids of the adipose depots in the lambs from the experimental group.

Conjugated linoleic acids (CLA) are geometrical and positional isomers of linoleic acid (Schmid et al., 2006) which are produced as a result of biohydrogenation of the dietary fatty acids in the rumen. Health effects including anticarcinogenic, hypocholesterolemic have been reported for the CLA in animals (Park et al., 1999; Miller et al., 2001). Several factors influences the CLA levels in the animal organism such as breed, slaughter weight, degree of fatness as of these feeding is one of the most important (Vatansever et al., 2000; Arsenos et al. 2006). The content of the CLA in our study was not influenced by the coconut oil supplementation in all the fat depots. In his experiment Manso et al., 2009 showed no significant effect of the palm oil supplementation on the content of the CLA in lambs.

Stearoyl-CoA desaturase catalyzes the conversion of the saturated C16:0 and C18:0 to C16:1 and C18:1, which are the major monounsaturated fatty acids in the lipids in lambs (Diaz et al., 2003). Its activity, described by the SCD index was lower ($P<0.01$) in the fat depots of the lambs fed coconut oil and corresponded to the changes of the content of the oleic acid. Its values also varied in depot specific way ($P<0.001$), being the lowest in the internal fat depots. This is in agreement with the results of other experiment (Banskalieva et al., 2005) where we reported lower activity of stearoyl CoA desaturase in abdominal and perirenal fat compared to subcutaneous. Our findings coincided with those published by Castro et al., 2005 and Moibi and Christopherson, 2001.

Lambs from the coconut oil supplemented group had lower elongase activity, described by the values of the elongase index. The main site for fatty acid elongation is the endoplasmic reticulum membrane, though it occurs in the mitochondria and microsomal membranes as well (Zhang et al., 2007). Generally, fatty acyl-CoA substrates in the range of C10-C14 are used by the mitochondrial elongation system, whereas microsomal elongases act on C16 and longer fatty acids (Harwood, 1994). It could be suggested that the increased amount of C16:0 in the fat depots is connected with greater content of substrates (C12:0 and C14:0) for the microsomal elongation whereas the reduced amount of C18:0 could be due to suppressed mitochondrial elongase activity.

CONCLUSIONS

The dietary coconut oil supplementation did not influence significantly the lipid deposition of the lamb carcasses although trends towards higher thickness of the subcutaneous adipose tissue existed in the lambs from the experimental groups. Significant difference ($P<0.001$) in the lipid deposition dependent on the site was observed.

The inclusion of the coconut oil in the diet of lambs led to significant increase ($P<0.001$) of the lauric, myristic and palmitic fatty acid, the total amount of the saturated fatty acid and the values of the atherogenic index thus indicating a certain unfavourable effect of the dietary coconut oil supplementation in amount of 20 g/d per animal.

The content of stearic acid as well as the stearoyl-CoA desaturase and elongase activities and polyunsaturated fatty acids were lower in response to coconut oil supplementation.

For most of the fatty acids depot specific influence was observed.

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