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Fatty Acid Profiles of *Supraspinatus*, *Longissimus lumborum* and *Semitendinosus* Muscles and Serum in Kacang Goats Supplemented with Inorganic Selenium and Iodine

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ABSTRACT: Fat and fatty acids in muscle and adipose tissues are among the major factors influencing meat quality particularly nutritional value and palatability. The present study was carried out to examine the effects of supplementing inorganic selenium (Se), iodine (I) and a combination of both on fatty acid compositions in serum, and *supraspinatus* (SS), *longissimus lumborum* (LL), and *semitendinosus* (ST) muscles in goats. Twenty-four, 7 to 8 months old, Kacang male goats with a mean live weight of 22.00±1.17 kg were individually and randomly assigned into four groups of six animals each for 100 d of feeding prior to slaughter. The animals were offered the same concentrate (basal) diet as 1% of body weight with *ad libitum* amount of fresh guinea grass. The four groups were as follows: T1 (control) - basal diet without supplementation; T2 - basal diet with 0.6 mg Se/kg DM; T3 - basal diet with 0.6 mg I/kg DM; T4 - basal diet with combination of 0.6 mg Se/kg DM and 0.6 mg I/kg DM. The major fatty acids (FAs) detected in the serum were palmitic (C16:0), stearic (C18:0), oleic (C18:1n9) and linoleic (C18:2n-6), while the major FAs in the selected muscles were C16:0, C18:0 and C18:1n9 acids. The main polyunsaturated fatty acids (PUFA) detected in muscles and serum were (CI8:2n-6), linolenic acid (C18:3n-3), and arachidonic acid (C20:4n-6). No significant differences ($p>0.05$) were observed in the concentration of total saturated fatty acids (SFA) among the four groups. PUFA concentrations in the goats supplemented with Se (T2) were significantly higher ($p<0.05$) than the goats of the control group (T1). The PUFA: SFA ratio was significantly higher in the animals supplemented with dietary Se (T2) than those of control ones (T1). It is concluded that dietary supplementation of inorganic Se increased the unsaturated fatty acids in muscle. The supplementation of iodine with or without Se had negligible effects on muscle fatty acid content of Kacang crossbred male goats. (**Key Words:** Fatty Acids, Selenium, Iodine, Serum, Goat Meat)

INTRODUCTION

Fat and fatty acids in muscle and adipose tissues are the major factors which significantly affect meat eating quality particularly the nutritional value (Wood et al., 2008) and palatability (Smith et al., 2004). Changes in the dietary fatty acid (FA) composition could be reflected in the blood which in turn will be transported to the various target organs (Chilliard et al., 2007) such as the three muscles [*supraspinatus* (SS), *longissimus lumborum* (LL) and *semitendinosus* (ST) examined in the present study. The fatty acids present in the muscle and in the intramuscular adipose tissue are the main forms of intramuscular fat (IMF). The intramuscular adipose tissue is found along the fibres and in the interfascicular area and contains mainly triacylglycerol (neutral lipid). The lipids of the muscle fibres contain significant proportion of phospholipids, triacylglycerol, as well as cholesterol (Raes et al., 2004). The fatty acids of triacylglycerol are made up mainly of

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saturated fatty acids (SFAs) and monounsaturated fatty acids (MUFA). On the other hand, the phospholipid fraction has a higher proportion of polyunsaturated fatty acids (PUFAs), which is strictly controlled as a component of cellular membranes (De Smet et al., 2004). The phospholipid content in the muscle is also noted to be quite constant and less affected by genetic and nutritional factors (Raes et al., 2004). It has been reported that red muscles contain a higher proportion of phospholipids than white muscles and thus relatively higher amount of PUFA (Wood et al., 2003).

Muscle lipids in ruminants frequently present a high content of SFAs (Aurousseau et al., 2004), as a result of the microbial biohydrogenation process occurring in the rumen (Jenkins et al., 2008). However, the SFA content in muscle lipids are typically much lower compared to that in the subcutaneous fats (Wood et al., 2003). Oleic (C18:1), palmitic (C16:0), stearic (C18:0) and linoleic (C18:2n-6) acids are the main FAs present in the muscle lipid of goats (Banskalieva et al., 2000).

The levels of SFAs such as myristic (C14:0) and C16:0 in meat is of special nutritional concerns among consumers in the light of their role in increasing plasma low density lipoprotein (LDL) cholesterol, the main risk factor for cardiovascular diseases in human (Leheska et al., 2008).

Apart from the SFA, ruminants also have sizable portions of MUFA amongst their muscle lipids. The major MUFAs are C18:1 followed by palmitoleic (C16:1) and vaccenic acid (*trans*11-18:1), the products of incomplete biohydrogenation of 18:2n-6 and 18:3n-3 in the rumen. It has been reported that high levels of t-C18:1 in the human diet increase high density lipoprotein (HDL) cholesterol and reduce the LDL- cholesterol concentrations in plasma, where the latter is associated with coronary heart disease (Katan et al., 1994). A cumulative intake of *trans* fatty acid (*t*-FAs) has been discouraged because of their adverse effects on human blood cholesterol (Field et al., 2009). However, Griinari et al. (2000) indicated that vaccenic acid performs as a substrate for the formation of conjugated linoleic acid (CLA) in animal tissues. Additionally, Field et al. (2009) suggested that consumption of t-18:1 is not associated with coronary heart disease, and may convey health benefits beyond those related with CLA.

The main two fatty acids which are not synthesized *de novo* by animal cells, are linoleic (LA, C18:2n-6) and α-linolenic (ALA, C18:3n-3) acids (Simopoulos, 2008). Linoleic acid, normally high in grains, can be converted to longer chain n-6 fatty acid as arachidonic acid (C20:4n-6). Linolenic acid, normally high in grass and leaves, can be converted to longer chain n-3 fatty acids such as eicosapentaenoic (C20:5n-3) and docosahexaenoic (C22:6n-3) acids (Wood et al., 2003).

The ruminant products have higher concentrations of CLA mainly c9t11CLA than those from non-ruminants (Chin et al., 1992). It has been reported that CLA have several beneficial effects in health-related disorders (Bhattacharya et al., 2006). The endogenous synthesis of c9t11CLA is formed by the action of Δ^9 desaturase enzyme on t11C18:1, which is the intermediate product of microbial biohydrogenation of LA and LNA acids in the rumen. It has been thought that increasing t11C18:1 production in the rumen will increase c9t11CLA tissue levels (Raes et al., 2004).

The PUFA/SFA and n-6/n-3 FAs ratios are usually used to evaluate the nutritional value of fat food. The recommended ratio in human diets is 0.45 for the PUFA/SFA ratio (British Department of Health, 1994) and 4:1 for the n-6/n-3 (Simopoulos, 2008). Increasing n-3 fatty acids content in ruminant products and decreasing their SFAs using nutritional resources containing oilseeds or a particular oil could achieve one of the important research goals to modify FA content of these products.

The increase in demand for goat meat is largely owed to the increase of ethnic populations, and the consciousness of health aware consumers of lower fat in goat meat compared to other red meats. Additionally, cooked goat meat has lower saturated fatty acid levels and cholesterol content when compared to other red meats (USDA, 1989).

Several reports showed that dietary Se supplementation did not affect FA profile in calves (Skrivanova et al., 2007) and lambs (Liu et al., 2011). The FA content of muscle lipids in goats is comparable to other ruminants, except that the PUFA content of muscle lipids in goats is higher than in mutton and beef (Banskalieva et al., 2000). However, it has been reported that Se is an important component of glutathione peroxidase (GSHPx) enzyme which may reduce the risk of peroxidation of PUFA (Traulsen et al., 2004). There are no references on the effect of dietary I on the FA composition in goats. Not only that, but studies related to the effect of dietary Se on the level of FA in goats are also limited. The objective of the current study was, therefore, to evaluate the effect of dietary supplementation of inorganic selenium as sodium selenite, inorganic iodine as potassium iodide, and a combination of both on the intramuscular fatty acid composition of three different muscles in Kacang crossbred male goats.

MATERIALS AND METHODS

The experiment was conducted following the guidelines of the research policy of the Universiti Putra Malaysia on animal ethics and welfare.

Animals and diets

Twenty-four, 7 to 8 months old local Kacang crossbred male goats with a mean live weight of 22.00±1.17 kg were

obtained from a commercial breeder farm and were randomly assigned into four dietary treatments of six animals each for 100 d of feeding prior to slaughter. The animals were housed individually in wooden slatted floor pens measuring 1.20 m×0.80 m each, 0.70 meter above ground, equipped with feeding and drinking facilities. The animals were offered the same concentrate diet (43% palm kernel cake, 30% rice bran, 25% corn, 1% $CaCO_3$, 0.5% NaCl, 0.5% minerals-vitamins mix) as 1% of body weight with *ad libitum* amount of fresh guinea grass. Feed intake of each animal was recorded daily based on the amount of feed offered and refusals to calculate the amount of Se and I. The four dietary treatments were as follows: T1 (control) - basal diet without supplementation; T2 - basal diet with 0.6 mg Se/kg DM; T3 - basal diet with 0.6 mg I/kg DM; T4 - basal diet with combination of 0.6 mg Se/kg DM and 0.6 mg I/kg DM. The amount of Se and I in the basal diet was 0.124 and 0.025 mg/kg feed respectively. The inorganic selenium was given in the form of sodium selenite (R&M Chemicals, UK) while the inorganic iodine was given in the form of potassium iodide (BHD Lab, UK). Inductively Coupled Plasma - Mass Spectrometry (ICP-MS; ELAN DCR-e Perkin Elmer, Canada, 2008) was used for quantitative determination of Se and I in processed samples using Se standard (Perkin Elmer Pure Plus Multi-element ICP-MS Calibration Std.3, USA) and I standard (Anion Standard Iodide As-19-24 SPEX Certiprep, USA). The determination of dry matter (DM), crude protein (CP), ether extract (EE) and ash (Table 1) was conducted following the method of AOAC (1984). The method of Van Soest and Wine (1967) was employed to determine the neutral detergent fibre (NDF) and acid detergent fibre (ADF) using (Fibertec System M 1020 Hot Extractor, Tecator). The amount of selenium (0.6 mg/kg DM) and iodine (0.6 mg/kg DM) was calculated to ensure supply of twice of the requirements by goats (NRC, 1981). The levels of 0.6 mg/kg DM of I and Se were chosen as to avoid any toxicity via the dietary supplementation. The toxicity level for iodine exceeding 4 mg/d, while for selenium the toxicity level exceeding 3 mg/d (NRC, 1981).

Table 1. Chemical composition and fatty acid profile of the basal diet and fresh guinea grass fed to goats in all treatments

Composition	Basal diet	Guinea grass
Dry matter (%)	90.32	30.25
Crude protein (%)	12.90	6.92
Ether extract (%)	3.28	1.8
Ash (%)	9.43	4.65
Neutral detergent fibre (%)	55.75	69.22
Acid detergent fibre (%)	25.92	48.13
Fatty acid (% of total identified fatty acids)		
C12:0	3.12	-
C14:0	1.64	-
C15:0	0.22	2.46
C16:0	18.64	32.22
C16:1	0.64	3.68
C17:0	0.56	2.67
C18:0	7.50	4.23
C18:1n-9	27.89	7.97
C18:2n-6	36.75	21.02
C18:3n-3	0.67	25.76
C20:4n-6	1.09	-
C20:5n-3	1.29	-

Serum and muscle sampling

Blood samples from each individual animal were collected at day 95 of the experiment. Samples were collected aseptically through jugular venipuncture, using 21- gauge needles into a 10 mL Vacutainer (BD Franklin Lakes NJ, USA) serum tubes which were later kept slanting for 1 h, followed by centrifugation at 3,000 g for 10 min. The resulted serum was frozen at −20°C until subsequent fatty acids determination. Upon accomplishment of the feeding trial, the animals were slaughtered and samples of SS, LL, and ST muscles were dissected, trimmed of any visible fat and connective tissue, snap frozen in liquid nitrogen, and stored at −80°C until subsequent fatty acids determination.

Fatty acid determination

The total fatty acids from feed, meat and blood were extracted using the method described by Rajion et al. (1985). Approximately 1 g of meat and feed samples were homogenized (Heidolph DIAX 600, Germany) or 2 mL of serum were mixed with 40 mL of chloroform: methanol at 2:1 (v/v) and allowed to stand for 12 h with occasional shaking. The mixture was then filtered through a No. 1 Whatman filter paper (Whatman International Ltd., Maidstone, UK) into a 250 mL separated flask. Ten millilitres of normal saline solution were then added to facilitate phase separation. The entire mixture was shaken vigorously for one minute and left to stand for 4 h. After complete separation, the lower chloroform phase was collected into a round bottom flask and rotary evaporated (Heidolph W B 2001, Germany) at 70°C. A portion of 5 mL of fresh chloroform:methanol, 2:1 (v/v) was then added and the lipid extract was transferred into a capped 10 mL methylation tube.

Prior to transmethylation, a fixed amount of heneicosanoic acid (C21; Sigma Co., St Louis, MI, USA) was added to the extract as an internal standard. The lipid extract was air-dried under a steady flow of pure nitrogen (Malaysia Oxygen., Bhd, Malaysia) on a heating block at 40°C. Thereafter, 2 mL of 0.66 N of methanolic KOH (R&M Chemicals, Essex, UK) were added to saponify the lipid extract, and the tubes were capped and transferred to a

water bath at 80°C for 10 min with occasional shaking. Once cooled down, 2 mL of 14% methanolic boron trifloride (Sigma Co., St Louis, MI, USA) were added and the tubes were capped and reheated in a boiling water bath for 20 min with occasional shaking (Rajion et al., 1985). Upon cooling the tubes, 4 mL of petroleum ether (Merck, Germany) and 2 mL of ddH_2O were added. The tubes were then shaken vigorously for 1 min and centrifuged at 3,000 g for 10 min. The upper petroleum ether phase was transferred to a glass test tube and washed with 1 mL of ddH_2O. The upper layer was then transferred to another glass test tube and 0.5 g of anhydrous sodium sulphate (R&M Chemicals, Essex, UK) was added to remove residual moisture. The petroleum ether containing FAME was transferred into 1.5 mL screw-capped vial, flushed with pure nitrogen and stored at 4°C for gas liquid chromatography analysis.

Following to that, the FAMEs were separated on a HP-88 (J&W Scientific Columns from Agilent, USA), fused silica capillary column (60 m, 0.25 mm ID, 0.20 μm film thickness) in a Gas Liquid Chromatography (6890N, Agilent Technologies, USA). The identification of peaks was made by comparing the retention time against those of authentic standards (Sigma, Chemicals) based on their equivalent chain lengths. The fatty acid concentrations were expressed as percentages of the total identified fatty acids.

Statistical analysis

The experiment was of a completely randomised design (CRD). The experimental unit was the animal for all the variables measured during the whole study. Data of serum and muscle fatty acids were subjected to one-way analysis of variance (ANOVA) using a model that included treatment and animal as possible sources of variation. The data were statistically analysed using the Statistical Analysis System (SAS) package Version 9.2 software (SAS, 2007) at 95% confidence level. The Duncan multiple range test was used to test the significance of variance between the means of the studied parameters.

RESULTS

Serum and muscle fatty acid profiles

The results obtained for serum FA were as presented in Table 2. The FA composition of the SS, LL, and ST muscles in goats fed experimental diets were as presented in Table 3, 4, and 5, respectively. The major FAs detected in the serum were C16:0, C18:0 and C18:1n9 which accounted for more than 70%, in addition to C18:2n-6, which accounted more than 13% of total fatty acids. The major FAs in the selected muscles were C16:0, C18:0 and C18:1n9 acids, which accounted for more than 70% of total FAs, while the main PUFA detected in muscles and serum was CI8:2n-6, C18:3n-3, and C20:4n-6.

Table 2. Serum fatty acid composition (% of total identified fatty acids) in goats fed experimental diets

Fatty acids	Dietary treatments[1]				
	T1	T2	T3	T4	SEM
C16:0	20.32	19.99	19.69	19.16	0.52
C16:1	2.28	2.46	2.81	2.42	0.25
C17:0	2.09	2.04	1.64	1.85	0.21
C18:0	23.49[b]	24.64[ab]	26.13[a]	26.59[a]	0.81
C18:1n-9	31.59	30.81	30.79	30.37	1.10
C18:2n-6	14.38	14.53	13.26	13.63	1.20
C18:3n-3	1.14	1.27	1.18	1.33	0.17
C20:4n-6	4.75	4.42	4.65	4.58	0.53
SFA[2]	45.90	46.67	47.46	47.60	1.08
UFA[3]	54.13	53.49	52.69	52.33	1.08
MUFA[4]	33.87	33.27	33.60	32.79	1.10
PUFA-n6[5]	19.13	18.95	17.91	18.21	1.20
PUFA-n3[6]	1.14	1.27	1.18	1.33	0.11
PUFA[7]	20.27	21.52	19.09	19.54	1.20
UFA:SFA	1.18	1.15	1.11	1.10	0.06
PUFA:SFA	0.44	0.46	0.40	0.41	0.03
n6:n3	16.78	14.92	15.17	13.69	0.98

[1] T1 = Control, basal diet without supplementation; T2 = Basal diet+0.6 mg Se/kg DM; T3 = Basal diet+0.6 mg I/kg DM; T4 = Basal diet+(0.6 mg Se/kg DM+0.6 mg I/kg DM).
[2] Total saturated fatty acids. [3] Total unsaturated fatty acids.
[4] Total monounsaturated fatty acids.
[5] Total polyunsaturated fatty acids n-6.
[6] Total polyunsaturated fatty acids n-3.
[7] Total polyunsaturated fatty acids.
[ab] Means with different superscripts within the same rows differ significantly ($p<0.05$).
SEM = Standard error of means.

The concentration of C18:0 in the serum was significantly ($p<0.05$) higher in the animals of T3 and T4 compared to the animals of control group (T1). No significant differences were observed in any of the SFA in the SS muscle except for C18:0 which was significantly higher in the control group (T1) than the group supplemented with the combination of Se and I (T4). However, no differences ($p>0.05$) were observed in the concentration of total SFA between the treatments. The concentration of CI8:2n-6 in the goats supplemented with Se (T2) were significantly higher ($p<0.05$) than those of the control group (T1). Additionally, the concentrations of C20:4n-6 and C18:3n-3 in the animals supplemented with Se (T2) was significantly higher ($p<0.05$) compared with the animals supplemented with iodine (T3) and control groups (T1). The concentration of PUFAn-6 in the animals of group T2 was significantly ($p<0.05$) higher than the animals of T1 and T4. The concentration of PUFAn-3 in the animals supplemented with Se (T2) was significantly higher ($p<0.05$) compared with those of T3 and T1. The PUFA:

Table 3. Fatty acid composition (% of total identified fatty acids) of the intramuscular fat from the *supraspinatus* muscle in goats fed experimental diets

Fatty acids	Dietary treatments[1]				
	T1	T2	T3	T4	SEM
C14:0	3.10	2.50	2.35	2.20	0.54
C15:0	3.02	3.81	4.30	3.14	0.52
C16:0	21.10	20.79	21.43	20.16	1.50
C16:1	2.33	2.17	1.95	2.20	0.20
C17:0	3.31	3.40	3.28	3.32	0.52
C18:0	17.56^{a}	16.25^{ab}	16.13^{ab}	15.69^{b}	0.47
C18:1n-9	37.06	34.78	35.72	39.86	2.10
C18:2n-6	8.54^{b}	11.21^{a}	10.54^{ab}	9.57^{ab}	0.65
C18:3n-3	0.64^{c}	1.02^{a}	0.79^{bc}	0.87^{ab}	0.06
C20:4n-6	3.12^{b}	4.90^{a}	3.49^{b}	3.74^{ab}	0.39
SFA[2]	48.46	46.70	47.49	44.67	1.14
UFA[3]	51.53	53.29	52.49	55.33	1.15
MUFA[4]	39.37	36.87	37.17	42.06	2.17
PUFA-n6[5]	11.65^{b}	16.43^{a}	14.02^{ab}	13.28^{b}	0.84
PUFA-n3[6]	0.64^{c}	1.02^{a}	0.79^{bc}	0.87^{ab}	0.06
PUFA[7]	12.29^{b}	17.45^{a}	14.81^{ab}	14.14^{b}	0.87
UFA:SFA	1.07	1.14	1.11	1.24	0.05
PUFA:SFA	0.25^{c}	0.37^{a}	0.32^{ab}	0.31^{b}	0.01
n6:n3	18.28	16.10	17.74	15.35	1.66

[1] T1 = Control, basal diet without supplementation; T2 = Basal diet+0.6 mg Se/kg DM; T3 = Basal diet+0.6 mg I/kg DM; T4 = Basal diet+(0.6 mg Se/kg DM+0.6 mg I/kg DM).
[2] Total saturated fatty acids. [3] Total unsaturated fatty acids.
[4] Total monounsaturated fatty acids.
[5] Total polyunsaturated fatty acids n-6.
[6] Total polyunsaturated fatty acids n-3. [7] Total polyunsaturated fatty acids.
[abc] Means with different superscripts within the same rows differ significantly ($p<0.05$).
SEM = Standard error of means.

Table 4. Fatty acid composition (% of total identified fatty acids) of the intramuscular fat from the *longissimus lumborum* muscle in goats fed experimental diets

Fatty acids	Dietary treatments[1]				
	T1	T2	T3	T4	SEM
C14:0	2.52	2.19	1.79	2.04	0.28
C15:0	2.70	2.92	4.06	3.46	0.49
C16:0	23.61^{a}	21.25^{b}	20.06^{b}	20.26^{b}	0.86
C16:1	2.17	1.80	2.10	2.26	0.25
C17:0	2.80	3.60	4.09	3.51	0.57
C18:0	18.56	17.40	17.96	17.73	0.80
C18:1n-9	36.64	34.62	33.75	37.66	2.57
C18:2n-6	6.55	9.98	10.64	8.06	1.51
C18:3n-3	0.59^{b}	0.99^{a}	0.87^{a}	0.86^{a}	0.04
C20:4n-6	3.62	5.32	5.43	4.47	0.72
SFA[2]	50.15	47.36	47.39	46.93	1.30
UFA[3]	49.88	52.71	52.61	53.11	1.31
MUFA[4]	38.99	36.38	35.84	39.86	2.55
PUFA-n6[5]	10.30	15.46	16.05	12.65	2.02
PUFA-n3[6]	0.59^{b}	0.99 ^{a}	0.87^{a}	0.86^{a}	0.04
PUFA[7]	10.86	16.45	16.92	13.50	2.05
UFA:SFA	1.00	1.12	1.11	1.13	0.06
PUFA:SFA	0.22	0.35	0.36	0.29	0.04
n6:n3	17.45	15.34	18.22	14.79	1.74

[1] T1 = Control, basal diet without supplementation; T2 = Basal diet+0.6 mg Se/kg DM; T3 = Basal diet+0.6 mg I/kg DM; T4 = Basal diet+(0.6 mg Se/kg DM+0.6 mg I/kg DM).
[2] Total saturated fatty acids. [3] Total unsaturated fatty acids.
[4] Total monounsaturated fatty acids.
[5] Total polyunsaturated fatty acids n-6.
[6]Total polyunsaturated fatty acids n-3.
[7] Total polyunsaturated fatty acids.
[ab] Means with different superscripts within the same rows differ significantly ($p<0.05$).
SEM = Standard error of means.

SFA ratio was significantly higher in T2 than T1and T4.

The dietary supplementation of Se, I, and their combination had limited effects on the FA composition of the LL muscle. The concentration of C16:0 in the LL muscle was significantly ($p<0.05$) lower in the animals of the supplemented groups (T2, T3, and T4) than those assigned as controls. Additionally, the concentrations of C18:3n-3 and PUFA n-3 were significantly higher in the LL muscle in the animals of T2, T3, and T4 compared with those of T1.

In the ST muscle, the concentration of C16:1 was significantly higher ($p<0.05$) in the animals of the control group (T1) than the T3 and T4 animals. Higher ($p<0.05$) concentrations of C18:0 were observed in T4 animals than in T2 and T1 animals. The dietary supplementation of Se (T2) significantly increased ($p<0.05$) the concentrations of C18:3n-3 and PUFA n-3 in the ST muscle compared with T1 and T3 groups. The concentration of C20:4n-6 was significantly higher in the animals supplemented with Se (T2) than those of control group (T1).

DISCUSSION

In general, it was noted that only the unsaturated fatty acids were slightly affected by the Se supplementation. The iodine supplementation with or without Se generally had no significant effects on the muscle tissue fatty acids. These results could be explained by the association between Se and the antioxidative pathways in tissues rendering an added degree of protection to easily oxidizable fatty acids such as those from n-3 PUFA in SS, LL, and ST muscles of the goats supplemented with dietary Se (T2).

The degree of FA saturation can affect the grade of fat firmness which in turn, could also affect the selling value and acceptability of meat (Perry et al., 1998). On the other hand, it is highly necessary to determine FA composition in the muscles as intramuscular fat is usually not trimmable and hence not removed before eating and this would consequently influence consumer's health. As expected, results from the present study indicated a high proportion of

Table 5. Fatty acid composition (% of total identified fatty acids) of the intramuscular fat from the *semitendinosus* muscle in goats fed experimental diets

Fatty acids	Dietary treatments[1]				
	T1	T2	T3	T4	SEM
C14:0	2.46	2.00	2.73	2.67	0.31
C15:0	3.96	4.29	3.80	3.23	0.48
C16:0	21.02	20.34	19.78	20.36	0.46
C16:1	3.08[a]	2.16[ab]	1.83[b]	2.08[b]	0.30
C17:0	3.66	3.84	3.55	3.77	0.39
C18:0	15.67[b]	15.59[b]	18.43[ab]	18.56[a]	0.88
C18:1n-9	36.27	34.55	32.04	34.32	2.32
C18:2n-6	10.21	10.47	11.42	10.03	1.28
C18:3n-3	0.72[c]	1.03[a]	0.88[b]	0.93[ab]	0.04
C20:4n-6	3.57[b]	5.73 [a]	5.10[ab]	4.22[ab]	0.62
SFA[2]	46.76	46.10	48.18	48.59	1.51
UFA[3]	53.33	53.95	51.82	51.48	1.51
MUFA[4]	39.23	36.70	33.78	36.06	2.42
PUFA-n6[5]	13.04	16.73	16.52	14.75	1.79
PUFA-n3[6]	0.72[c]	1.03[a]	0.88[b]	0.93[ab]	0.04
PUFA[7]	13.75	17.25	17.39	15.68	1.82
UFA:SFA	1.14	1.17	1.08	1.06	0.06
PUFA:SFA	0.30	0.37	0.36	0.32	0.03
n6:n3	17.86	16.24	18.77	15.86	1.33

[1] T1 = Control, basal diet without supplementation; T2 = Basal diet+0.6 mg Se/kg DM; T3 = Basal diet+0.6 mg I/kg DM; T4 = Basal diet+(0.6 mg Se/kg DM+0.6 mg I/kg DM).
[2] Total saturated fatty acids. [3] Total unsaturated fatty acids.
[4] Total monounsaturated fatty acids.
[5] Total polyunsaturated fatty acids n-6.
[6] Total polyunsaturated fatty acids n-3.
[7] Total polyunsaturated fatty acids.
[abc] Means with different superscripts within the same rows differ significantly ($p<0.05$).
SEM = Standard error of means.

SFA in goat muscle lipids and this could have resulted from microbial biohydrogenation process of the dietary unsaturated fat in the rumen.

Earlier studies have shown that dietary supplementation of Se did not affect the FA profile in calves (Skrivanova et al., 2007). Additionally, a high level of dietary Se (2.5 mg Se/kg diet) had no significant effects on FA concentrations in *longissimus dorsi* and *semimembranosus* muscles of Merino lambs (Liu et al., 2011). Health wise, goat meat has been classified better than beef and mutton (Banskalieva et al., 2000) due to its lower lipid content and higher content of UFA (Mahgoub et al., 2002; Webb et al., 2005) as well as lower cholesterol proportions (Naud'e and Hofmeyer, 1981).

Contrary to the results reported by Skrivanova et al. (2007), the dietary Se supplementation in this study revealed changes in the FA profile. This could be attributed to the fact that they used calves, while our study involved goats which are known to contain slightly more PUFA in their muscular lipids (Banskalieva et al., 2000). Nevertheless, our results are in agreement with Yu et al. (2008) who reported that dietary Se supplementation increased plasma and liver concentrations of C20:4n-6 in lambs fed diets containing sunflower oil. The authors postulated that Se could have influenced the metabolism of C20:4n-6 probably through the action of GSHPx in regulating biosynthesis of prostaglandins from arachidonic acid.

In the present study, the intramuscular fat from Kacang crossbred male goats was mainly composed of oleic followed by palmitic and stearic acids, which comprised more than 70% of the fatty acids composition, comparable to other literature values in Kacang crossbred male goats (Karami et al., 2011; Ebrahimi et al., 2012), Omani Jebel Akhdar goats (Mahgoub et al., 2002) and Pateri male goats (Talpur et al., 2008). The concentration of C18:0, a final product of complete biohydrogenation of C18:3n-3 and C18:2n-6, was increased noticeably in the serum and muscle compared to its concentration in the diet, while the opposite case was true for PUFA. Buccioni et al. (2012) reported that increasing UFA in the diet may increase the range of C18:2 and C18:3 biohydrogenation in rumen and these reactions seem to be a mechanism used by microorganisms to protect themselves from toxic effects of UFA (Dehority, 2003).

The major FA in ruminant meat is oleic acid (Wood et al., 2008). This fatty acid is shaped from C18:0 by Δ^9 desaturase enzyme, also known as stearoyl-CoA desaturase, and is more abundant in neutral lipid. The findings of Ebrahimi et al. (2012) on Kacang crossbred male goats, concurred with the present results on the MUFA content in LL muscle. Additionally, the muscle MUFA content in the present study is in agreement with previous report by Talpur et al. (2008) on the *longissimus dorsi* muscle of Pateri male goats. Conversely, a higher concentration of MUFA muscle fat in Australian feral goat has been reported (Werdi Pratiwi et al., 2007). This may be due to the increased intramuscular fat content in the *longissimus thoracis* muscle of the heavier animals.

The range of PUFA:SFA (P/S) ratios were higher in the supplemented group than the control and this may due to the lower concentration of C18:3n-3 in the latter. The range of P/S ratios in the goats of the present study was slightly higher than in the Pateri male goats of Talpur et al. (2008) and the Australian Boer and Feral goats of Werdi Pratiwi et al. (2006). However, the P/S ratios were lower than the nutritional recommendations of the British Department of Health (1994), which suggested the ratio of P/S for the healthy diets should be 0.45, or higher. The increase in the content of monounsaturated fatty acids (MUFA) and SFAs would also decrease the P/S ratio since the P/S ratio was calculated from the available FA data and their sum.

The n-6/n-3 ratio in all groups of muscles in the goats of

the present study was of a high range, and this could be due to the high amounts of linoleic acid in the diet. The n-6/n-3 ratio in the present study was higher than the recommended ratio (<4) for human health (Simopoulos, 2008). However, the recent western diets have 16 to 20 times more than the recommended level (Simopoulos, 2002). De Smet et al. (2004) have documented that the n-6/n-3 ratios are significantly affected by feeding factors of the animal, and for a certain diet, the n-6/n-3 ratios in very lean meat will be greater than in meat with a higher fat level.

In conclusion, the results of the present study showed that the PUFA concentrations in the muscles of goats supplemented with Se at the level of 0.6 mg/kg DM were significantly increased compared to the control animals. The PUFA:SFA ratio in LL muscle of the animals supplemented with dietary Se alone was markedly higher than the control group. The iodine supplementation with or without Se generally had slight effects on the tissue fatty acids. The data generated from this study also provide a basis for future work on the effect of combining the different levels of dietary Se with protected lipid supplements to increase muscle PUFA deposition.

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