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Oil Palm (*Elaeis guineensis* Jacq.) Frond Feeding of Goats in the Humid Tropics

[1]M. Ebrahimi, [1]M.A. Rajion, [1]Y.M. Goh, [2]A.Q. Sazili, [2]A.F. Soleimani and [3]J.T. Schonewille
[1]Department of Veterinary Preclinical Sciences, Faculty of Veterinary Medicine,
[2]Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia,
43400 UPM Serdang, Selangor, Malaysia
[3]Department of Nutrition, Faculty of Veterinary Medicine, Utrecht University,
P.O. Box 80152, 3508 TD Utrecht, The Netherlands

Abstract: Twenty four goats were allocated to three groups (n = 8) and fed either a control diet Without Oil Palm Fronds (CON), a diet incorporated with 25% Oil Palm Fronds (OPFM) or 50% Oil Palm Fronds (OPFH) for 100 days to evaluate their growth rates, carcass characteristics and subcutaneous fatty acid profiles. Animals in all three groups exhibited similar final body weights ($p>0.05$). The OPFH group showed a significant linear reduction ($p<0.05$) in dressing percentage, warm carcass weight and back fat thickness and total muscle when compared to the CON group. The total n-3 Polyunsaturated Fatty Acid (PUFA) concentrations in the subcutaneous fat of the OPFH animals were significantly higher (linear, $p<0.05$) than the CON group. The diet containing 25% of oil palm fronds did not produce any adverse effects on the growth performance and carcass characteristics. This demonstrates an environmental-friendly way of utilizing agricultural waste by products for the small ruminant industry in tropical countries growing oil palm tree.

Key words: Goat, oil palm fronds, fatty acid, carcass characteristics, chevon

INTRODUCTION

A major constraint in ruminant livestock production in tropical countries including Malaysia is the lack of grazing pasture and the difficulty in providing feed in sufficient quantities and with adequate nutrients throughout the year. One feasible strategy to ensure nutrient supply to ruminants is to utilize available indigenous agricultural by-product resources. Oil Palm Fronds (OPF) are one of the most available and abundant agricultural by products in Malaysia where the total production of OPF in Malaysia was estimated at 18.73 million metric tonnes dry matter per year (Goh *et al*., 2010). Therefore, OPF may be of great nutritional importance for ruminants and its potential as a source of roughage or as a component in mixed feeds for ruminants has been shown by Dahlan (2000).

Oil palm fronds which comprised branches, stems and leaves of the oil palm tree are rich in fiber (879 g NDF/kg DM, 774 g ADF/kg DM and 19.9 g ADL/kg DM (Ebrahimi *et al*., 2012). The high fiber content of OPF negatively affects the digestibility which results in an estimated ME value of 5.6 MJ/kg DM (Zahari *et al*., 2003). Besides the low ME value, OPF are also low in crude protein (34 g kg^{-1} DM) and crude fat (21 g kg^{-1} DM), (Ebrahimi *et al*., 2012). Therefore, the incorporation of high proportions of OPF into ruminant diets would negatively affect production. However, to the researchers knowledge there are no controlled data available in peer reviewed journals about the maximum inclusion levels of OPF in ruminant diets to safeguard production but inclusion levels up to 50 and 30% in beef and dairy rations, respectively were recommended by Dahlan (2000).

Apart from the relatively poor macronutrient profile, OPF might have an added value in relation to fat metabolism. In ruminants, PUFA are extensively biohydrogenated which results in increased levels of Saturated Fatty Acids (SFA) in the animal circulation and tissues (Jenkins *et al*., 2008). Consequently, beef and dairy products are rich in Saturated Fatty Acids (SFA) which may negatively affect human health. It has been shown by Rajion *et al*. (2001) that increased proportions of OPF increased the total n-3 Polyunsaturated Fatty Acids (PUFA) in sheep plasma. Thus, the feeding of OPF might result in the enrichment of adipose tissue (intramuscular and subcutaneous fat) with n-3 PUFA thereby potentially contributing to the improvement of human health (Kris-Etherton *et al*., 1999; Simopoulos, 1999). It was hypothesized that increasing amounts of

Corresponding Author: Mohamed Ali Rajion, Department of Veterinary Preclinical Sciences, Faculty of Veterinary Medicine, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

OPF in the diet of goats would increase the n-3 PUFA content of the subcutaneous fat. Therefore, local Kacang crossbred male goats were fed diets up to 50% OPF to measure responses on growth performance, carcass characteristics and fatty acid profiles of subcutaneous fat.

MATERIALS AND METHODS

Animal welfare: The study was undertaken following the guidelines of the Research Policy of the Universiti Putra Malaysia on animal ethics.

Animals and experimental design: Twenty four local Kacang (Devendra and Burns, 1983) crossbred male local goats with an initial body weight of 21.7±0.97 kg (mean±SE) and approximately 6 months of age were used. The animals were individually housed in wooden pens measuring 1.2×0.9 m each built inside a shed with slatted flooring above 2 m ground. The trial had a parallel design which lasted for 100 days and was preceded by a 21 days pre-experimental period. The animals were weighed monthly just before the morning feeding. The goats were randomly assigned to the three experimental diets, i.e., either 100% Concentrate (CON), 25% OPF (OPFM) or 50% OPF (OPFH).

Diets: Fresh OPF were chopped into 1-2 cm length, sun-dried for 3 days and pelleted (12 mm diameter). The ingredients and analyzed composition of the experimental diets are shown in Table 1. The diets were adjusted to be iso-caloric and iso-nitrogenous to balance the metabolizable energy content of the diets. All treatment diets were formulated according to NRC (1981) recommendations to meet their requirements. The raw OPF fatty acid profile contained 1901, 2012 and 545 mg/100 g Dry Matter (DM) of C18:1n-9, C18:2n-6 and C18:3n-3, respectively. The soybean meal fatty acid profile contained 319, 1194 and 102 mg/100 g DM of C18:1n-9, C18:2n-6 and C18:3n-3, respectively. The palm oil fatty aid profile contained 27 402, 6955 and 665 mg/100 mL of C18:1n-9, C18:2n-6 and C18:3n-3, respectively. They were fed at individual wooden cages at 3% of adjusted weekly body weight. The animals were fed twice daily at 8:00 and 17:00. Water was provided *ad libitum* and a mineral block was available at all times. Pelleted oil palm fronds were included in the ration by simply mixing with the daily allowance of the concentrate portion just before feeding.

Collection of samples and slaughtering procedure: The feed samples were collected every 2 weeks and pooled for the final analysis. The feeding trial lasted for 100 days with a 3 weeks adaptation period. Body weights were determined monthly and the growth performance assessed by the weights and Average Daily Gain (ADG). The animals were fasted for 12 h with free access to water before slaughtering. The goats were slaughtered according to the standard slaughter procedures outlined in the MS 1500:2004. The carcasses were dressed according to Colomer-Rocher *et al*. (1992). The carcasses were then chilled at 4°C for a 24 h period. Carcass parameters including warm carcass weight, dressing %, back fat thickness, rib eye area, total meat, total bone and total fat were measured post-slaughter. The meat pH of both warm and chilled carcasses were measured using a portable pH meter (Hanna Instruments, Woonsocket, RI, USA) by a penetrating probe inserted into the Longissimus Dorsi (LD) muscle. The meat pH was measured immediately after slaughter, 1 day and 1 week post-slaughter. Subcutaneous fat was taken from the superior LD muscle for fatty acid analyses. The back fat thickness was determined from the LD muscle using an aluminum ruler.

Table 1: Ingredient and analyzed composition of the experimental diets

	Experimental diets		
Diets	CON	OPFM	OPFH
Ingredient composition (%)			
Commercial concentrate	100.00	64.30	23.20
Oil palm fronds	-	25.00	50.00
Soybeanmeal, fat exctracted	-	09.50	21.90
Palm oil	-	01.20	04.30
Limestone	-	-	00.60
Analyzed composition			
Dry matter (%)	86.80	85.60	82.70
Metabolizable energy (Mcal kg^{-1})	02.45	02.49	02.45
Crude protein (%)	14.00	14.00	14.00
Ether extract (%)	05.70	05.50	06.70
NDF (%)	28.80	39.70	43.80
ADF (%)	14.30	20.60	26.10
Calcium (%)	00.80	00.90	00.80
Phosphorus (%)	00.36	00.35	00.25
Fatty acid composition (g/100 g FAME)			
Myrtic acid (C14:0)	05.80	03.70	01.50
Palmitic acid (C16:0)	18.40	20.00	21.20
Stearic acid (C18:0)	02.30	03.50	03.80
Oleic acid (C18:1n-9)	22.50	24.40	30.60
Linoleic acid (C18:2n-6)	49.30	44.70	38.90
α-Linolenic acid (C18:3n-3)	01.50	02.50	03.80
Arachidic acid (C20:0)	00.30	00.30	00.30

Carcass composition: Muscle and bone were separated and weighed individually. All fats from the carcass were trimmed and separated into either subcutaneous or intermuscular fats.

Chemical analyses: The Dry Matter (DM) was determined by oven drying in a forced-air oven for 24 h at 105°C (AOAC, 2000). The Kjeltec Auto Analyzer (Tecator, Hoganas, Sweden) was used to determine the nitrogen

content of the feed; a factor of 6.25 was used to convert nitrogen into crude protein. Ether Extracts (EE) were determined using a 2025 Soxtec Auto Analyzer (Tecator, Hoganas, Sweden). The ash content was determined by ashing the samples in a muffle furnace at 550°C for 4 h (AOAC, 2000). An adiabatic bomb calorimeter (LecoCorp., St. Joseph, MI, USA) was used for the measurement of Gross Energy (GE). The feed samples were analyzed for Neutral Detergent Fiber (NDF with heat stable amylase and sodium sulfite) and Acid Detergent Fiber (ADF) according to the method described by Van Soest *et al.* (1991). Values for NDF and ADF are expressed inclusive of the residual ash.

Determination of fatty acid profiles: The total fatty acids were extracted from experimental feeds and subcutaneous fat based on the method of Folch *et al.* (1957), modified by Rajion *et al.* (1985) as described by Ebrahimi *et al.* (2013) using chloroform:methanol 2:1 (v/v) containing butylated hydroxytoluene to prevent oxidation during sample preparation. The extracted fatty acids were transmethylated to their Fatty Acid Methyl Esters (FAME) using methanolic KOH in 14% methanolic boron trifluoride (BF_3) (Sigma Chemical Co. St. Louis, Missouri, USA) according to the methods by AOAC (2000). The FAME was separated by gas chromatography (Agilent 7890A) using a 100×0.25 mm ID (0.20 μm film thickness) Supelco SP-2560 capillary column (Supelco, Inc., Bellefonte, PA, USA). The 1 μL of FAME was injected by an auto sampler into the chromatograph, equipped with a Flame Ionization Detector (FID). The split ratio was 1:30 after injection of the FAME. The injector temperature was programmed at 250°C and the detector temperature was 300°C. The column temperature program initiated runs at 120°C held for 5 min increased by 2°C min^{-1} up to 170°C held at 170°C for 15 min increased again by 5°C min^{-1} up to 200°C and held at 200°C for 5 min and then increased again by 2°C min^{-1} to a final temperature of 235°C and held for 10 min. The fatty acid concentrations are expressed as g/100 g total identified fatty acids.

Statistical analysis: Results were analyzed using analysis of variance with different OPF levels as the main effects and the initial weight as a covariate. The initial weights were used in the model as covariate because they had a significant effect on some variables. When covariance was not significant it was removed from the model. Carcass characteristics and fatty acid data data were analyzed by one-way ANOVA using the MIXED procedure of the SAS (2001) Software package, Version 9.1 (SAS Inst. Inc., Cary, NC). The statistical models used the following equation:

$$Y_{ijk} = \mu + T_i + F_k + e_{ijk}$$

Where:

μ = The overall mean
T = The different OPF level
F = The animal effect
e = The residual error

The random effect was the animals. Means were separated using the pdiff option of the lsmeans statement of the MIXED procedure. Differences of $p<0.05$ were considered to be significant. The data were checked for normality using PROC UNIVARIATE of SAS Software and the results in the tables are presented as means±standard error of the mean.

RESULTS

Body weight, carcass characteristics and traits: The body weight, carcass characteristics and traits are presented in Table 2. The final body weights at the end of trial were similar for all treatment groups. The average daily gain was also not different between the treatment groups. The dressing percentages of the OPFH group (46.33%) was significantly lower (linear, $p<0.05$) than the CON (49.47%) group but was not significantly different ($p>0.05$) from the OPFM group (48.11%). The warm and chilled carcass weights followed the same pattern for the body weights in the order of CON>OPFM>OPFH for all treatment groups. The chilled carcass weights for all the groups were 91.85% of their warm weights. The pH of either warm or chilled carcass was similar for all groups where the values for OPFH (6.39) and OPFM (6.39) groups were slightly higher than the CON group (6.18).

The rib eye area of OPFH treatment groups was significantly lower (linear, $p<0.05$) than the CON group. The back fat thickness of the OPFH (2.00) animals was significantly lower (linear, $p<0.05$) than the OPFM (3.50) and CON (3.67) animals.

The OPFH animals which were slightly lighter at slaughter had a significantly lower (linear, $p<0.05$) amount of total muscles compared totheothergroups (Table 2). The total muscle weight in the CON animals was about 1.26 times greater than that of the OPFH animals. The subcutaneous fats were heavier in the CON and OPFM groups compared to the OPFH groups but not significantly different ($p>0.05$). The total bone weight was the same for all treatment groups.

Fatty acid content of subcutaneous fat: The major Saturated Fatty Acids (SFA) in the subcutaneous fat were palmitic (C16:0) and stearic (C18:0) acids and to a lesser extent myristic acid (C14:0), lauric acid (C12:0), capric acid

Table 2: Growth and selected carcass characteristic of goats fed the experimental diets

	Experimental diets				p-value	
Characteristics	CON	OPFM	OPFH	SEM	Linear	Quadratic
Initial weight (kg)	22.50	22.57	21.88	0.57	0.69	0.78
Final weight (kg)	30.42	30.14	27.53	0.61	0.08	0.40
Average daily gain (g day^{-1})	79.17	75.71	56.50	4.34	0.06	0.42
Dressing percentage (%)	49.47	48.11	46.33	0.76	0.03	0.91
Warm carcass weight (kg)[1]	15.02	14.50	12.75	0.38	0.03	0.45
Chilled carcass weight (kg)[2]	13.68	12.99	12.09	0.36	0.12	0.90
Warm meat pH[1]	6.18	6.39	6.39	0.06	0.19	0.41
Cold meat pH after 1 day[2]	6.00	5.88	5.98	0.05	0.90	0.35
Rib eye area (cm^2)	1.83	1.57	1.25	0.10	0.04	0.89
Back fat thickness (mm)	3.67	3.50	2.00	0.24	0.01	0.14
Total subcutaneous fat (kg)	0.38	0.37	0.27	0.03	0.27	0.60
Total muscle (kg)	9.39	8.95	7.42	0.36	0.04	0.49
Total fat (kg)	0.77	0.78	0.63	0.07	0.46	0.62
Total bone (kg)	3.18	2.88	3.35	0.12	0.62	0.19

[1]Warm weight and warm carcass pH were measured within one h post-slaughter; [2]Chilled weight, chilled carcass pH were measured at 24 h post-slaughter; [3]Rib Eye Area (REA) and back fat thickness were measured at locations between 12-13th ribs; [ab]Values with different superscripts within the row differ significantly at $p<0.05$

Table 3: Fatty acid profile (g/100 g total identified fatty acids) of subcutaneous fat of goats fed the experimental diets

	Experimental diets				p-value	
Contents	CON	OPFM	OPFH	SEM	Linear	Quadratic
Fatty acids						
C10:0	00.21	00.17	00.21	0.008	0.70	0.06
C12:0	00.26	00.17	00.23	0.016	0.40	0.03
C14:0	04.30	03.17	03.30	0.169	0.01	0.07
C14:1	00.18	00.22	00.18	0.018	0.89	0.38
C15:0	00.60	00.53	00.50	0.024	0.08	0.68
C16:0	26.61	27.00	27.43	0.400	0.43	0.99
C16:1	03.00	02.92	02.56	0.124	0.16	0.65
C17:0	01.59	01.29	01.26	0.067	0.05	0.37
C17:1	00.91	00.92	00.73	0.110	0.54	0.71
C18:0	23.28	24.64	25.73	0.435	0.02	0.88
C18:1	30.62	31.51	30.42	0.435	0.86	0.37
C18:1t-11	04.20	03.25	03.32	0.218	0.10	0.32
C18:2n-6	02.48	02.50	02.16	0.125	0.32	0.57
CLA c-12 t-10	00.32	00.24	00.27	0.016	0.17	0.15
CLA c-9 t-11	00.44	00.47	00.48	0.023	0.54	0.93
C18:3n-3	00.74	00.74	00.93	0.034	0.02	0.20
C20:4n-6	00.07	00.06	00.06	0.004	0.62	0.77
C20:5n-3	00.05	00.07	00.08	0.005	0.01	0.35
C22:5n-3	00.12	00.12	00.13	0.005	0.14	0.67
C22:6n-3	00.02	00.03	00.04	0.003	0.01	0.88
SFA[1]	56.85	56.97	58.65	0.520	0.17	0.54
UFA[2]	43.15	43.03	41.35	0.520	0.17	0.54
MUFA[3]	38.92	38.81	37.20	0.524	0.20	0.56
PUFA n-3[4]	00.92	00.96	01.18	0.042	0.01	0.31
PUFA n-6[5]	02.86	02.79	02.48	0.131	0.25	0.71
n-6:n-3 ratio	03.09	02.89	02.15	0.141	0.01	0.37
UFA:SFA	00.76	00.76	00.71	0.016	0.18	0.49
PUFA:SFA	00.07	00.07	00.06	0.003	0.54	0.63

[1]SFA = Σ (C10:0, C12:0, C14:0, C15:0, C16:0, C17:0, C18:0); [2]UFA = Σ (C14:1, C16:1, C17:1, C18:1, C18:2n-6, C18:3n-3, C20:4n-6, C20:5n-3, C22:5n-3, C22:6n-3); [3]MUFA = Σ (C14:1, C16:1, C17:1, C18:1); [4]Total n-3 = Σ (C18:3n-3, C20:5n-3, C22:5n-3, C22:6n-3); [5]Total n-6 = Σ (C18:2n-6, C20:4n-6)

(C10:0) and pentadecanoic acid (C15:0) (Table 3). The total SFA content did not show significant differences between all treatment groups.

The total Unsaturated Fatty Acid (UFA) content was not significantly different ($p>0.05$) between all treatment groups. Generally, the CON group accumulated more UFA in the subcutaneous fat compared to the other groups.

The Monounsaturated Fatty Acids (MUFA) contributed substantially (37.20-38.92 g/100 g total identified fatty acids) towards the high total UFA content of the subcutaneous fat in all the treatment groups. All treatment groups had similar amounts of MUFA which was in the order of CON>OPFM>OPFH with oleic acid being the single major contributor to the total MUFA of

the fat depot. The OPFH animals had a significantly higher (linear, $p<0.05$) level of α-linolenic acid (0.93 g/100 g) than theCON (0.74 g/100 g). The OPFH animals had the highest percentage of n-3 PUFA (1.18 g/100 g) compared to the CON animals (0.93 g/100 g). α-Linolenic acid was the major contributor to the overall n-3 PUFA profile in the subcutaneous fat. Eicosapentaenoic acid (C20:5n-3) and docosahexaenoic acid (22:6n-3) were also significantly higher (linear, $p<0.05$) in the OPFH group compared to CON group. The levels of conjugated linoleic acid (CLA, C18:2cis-9 trans-11 and C18:2cis-10 trans-12) detected were similar ($p>0.05$) for all treatment groups.

The total n-6 PUFA content in the subcutaneous fat for all treatment groups were not significantly different ($p>0.05$). The main contributors of n-6 PUFA were linoleic acid (C18:2n-6) and arachidonic acid (C20:4n-6).

The UFA:SFA ratio was always highest (0.76) in the CON group (Table 3). The OPFH animals had the lowest UFA:SFA ratio (0.71) among the three treatment groups while the ratio for the OPFM group was 0.75.

The OPFH animals had the lowest n-6:n-3 ratio (2.15) compared to the OPFM (2.89) and CON (3.09) animals (Table 3). The n-6:n-3 ratio was significantly lower (linear, $p<0.05$) in the OPFH compared to the CON animals. The PUFA:SFA ratio values in the subcutaneous fat were not significantly different ($p>0.05$) between treatment groups and rarely exceeded 0.07.

DISCUSSION

Body weight, carcass characteristics and traits: The present study showed that the oil palm fronds incorporated diets did not produce any adverse effects on both the health and growth performance of the animals. Although, many studies showed that the diet could affect carcass characteristics in ruminants, the varied levels of concentrate and oil palm fronds in the diets used in the present study did not influence most of the carcass traits measured. Normally, increasing the levels of dietary fiber would decrease the fat content of the carcass and non-carcass portions in sheep (Mahgoub *et al*., 2007). Although, the diets used in this study were iso-caloric and isonitrogenous, the quality of the feeds could still affect the metabolizable energy and the availability of the energy to the goats (Mahjoub *et al*., 2005). The availability of energy and protein of diets normally affect both the growth performance and carcass characteristics (Abdullah and Musallam, 2007). In this study although, the metabolisable energy was similar for all diets, the digestibility of the OPFH diet would be different from the CON diet as the former contained more fiber. This was reflected in some carcass characteristics such as the lower dressing percentage, lower warm carcass weight and lower back fat thickness in the OPFH group compared to the CON animals.

The pH of the muscle is regarded as one of the important parameters affecting meat quality (Devine *et al*., 1993). The pH in the Kacang goat recorded in the present study was similar to that reported by Marinova *et al*. (2001) but higher than those reported by Kannan *et al*. (2001) in goats and Kadim *et al*. (2004) in Omani goats. The differences between breeds, treatment diets and the muscle fiber proportions (red or white) might explain these differences (Kannan *et al*., 2002). The treatment diets did not change significantly the pH of warm and cold meat in this study.

Due to the treatment effects, the carcass fat content tended to be lower in the OPFH group (0.88 kg) than the OPFM (1.13 kg) and CON (1.08 kg) group. It can be concluded that the OPF intake could have reduced carcass adiposity as reported by Goh (2002) for Barbados Black Belly x Malin crossbred rams. Feeding date palm fronds to sheep reduced significantly the carcass fat content (Mahgoub *et al*., 2007) which agrees with the current result. Goh (2002) had also shown that feeding high levels of oil palm fronds to sheep also reduced significantly the total amount of subcutaneous fat. It can be concluded that the utilization of high levels of oil palm fronds in the goat diet such as in the OPFH group, reduced the fat content of the carcass. The overall low amount of fat in the goat carcass can be explained by the low digestibility of the oil palm fronds which leads to lower nutrient utilization by the animals (Dahlan, 2000). The total bone weight was also not significantly different between all treatment groups in this study suggesting that at this stage of the animal's age the development of bone was not affected by the dietary treatment.

Fatty acid profiles: Feeding tree leaves to ruminants increased the n-3 PUFA content in meat and adipose tissue (Bas *et al*., 2005) in goats. The fatty acid composition of the subcutaneous fat in the present study which primarily comprised oleic (30.42-31.51 g/100 g) followed by palmitic (26.61-27.43 g/100 g) and stearic acid (23.28-25.73 g/100 g) was similar to those reported by Dhanda *et al*. (2003). The SFA content averaging 56.85-58.65 g/100 g was similar to those reported by Mahgoub *et al*. (2002). The combined palmitic, stearic and oleic acids which comprised a large proportion of the fatty acids in the adipose tissue (80.313-84.678 g/100 g) was similar to the report of Potchoiba *et al*. (1990) but lower than that of Gaili and Ali (1985). These differences may be attributed to the age, sampling location and/or the type of

feeds used. The total n-3 fatty acid content of adipose tissue in this study was significantly higher ($p<0.05$) in the OPFH group compared to the CON group. This was also observed by Bas *et al.* (2005) in the local goats of Morocco feeding in the Argan tree forest and obserbed by Marume *et al.* (2012) in Xhosa lop-eared goat using Acacia leaves. The higher percentage of n-3 fatty acids in the adipose tissues of the OPFH group fed high levels of oil palm fronds was due to the higher levels of n-3 fatty acids present in the oil palm fronds used in the feeds as reported by Ebrahimi *et al.* (2012). The n-6:n-3 ratios ranging 2.15-3.09 encountered in this study were also lower than the 15.3 reported by Bas *et al.* (2005). The decreased n-6:n-3 ratio in the OPFH group indicated that the fatty acid composition of the goat adipose tissue has been improved because of the inclusion of the oil palm fronds in the diet from a human health perspective. The low ratios of n-6:n-3 (2.15) observed in this study are a characteristic of fat from ruminants that are fed forage based diets which contains high levels of 18:3n-3 (De Smet *et al*., 2004). The total SFA and trans fatty acid in the subcutaneous fat for all treatment groups were similar. This result is in line with Goh (2002) who showed that the inclusion of oil palm fronds in the sheep diet can reduce the SFA and trans fatty acids. Rajion *et al.* (2001) showed that feeding oil palm fronds to Barbados Black Belly x Malin crossbred rams also increased n-3 PUFA content of their plasma and tissues which may be due to decreased biohydrogenation. Oil palm fronds contain high levels of secondary metabolites such as polyphenols and tannins (Rosalina *et al*., 2011) which can reduce the biohydrogenation in the ruminant (Cabiddu *et al*., 2010; Vasta *et al*., 2009).

The PUFA:SFA and n-6:n-3 ratios are commonly used to assess the nutritional value and healthiness of ruminant products for human consumption (Alfaia *et al*., 2007). Normally, the recommended PUFA:SFA ratio in human diets should be above 0.4 (Higgs, 2002). The PUFA:SFA ratios obtained in this study were above the recommended range (0.07) and could have beneficial effects for human health in preventing the development of cardiovascular diseases and some cancers (Mapiye *et al*., 2011).

CONCLUSION

The results of this study showed that the diets incorporated with oil palm fronds can be used without adversely affecting the body weight and carcass quality of the male Kacang crossbred goats. The abundant availability of oil palm fronds makes it an important feed source for goats especially in countries lacking grazing pasture but have vast oil palm plantations such as Malaysia. The availability and utilization of various by products in the oil palm plantation, particularly the oil palm fronds will provide suitable opportunities for a more practical and more sustainable goat production system. The results of the present study clearly showed that diets could be incorporated up to 25% w/w of oil palm fronds without any negative effects on the body weight and carcass characteristics of the finished chevon. In fact, the increased n-3 PUFA in the body tissue would make it more appealing to the health conscious consumer.

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