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Fatty Acid Profiles and Cholesterol Composition of Venison from Farmed Deer

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Abstract: It is important to evaluate venison characteristics as a new high quality red meat in the meat marketing system. This information is vital to ensure their commercial success and dietary benefits. The aim of this study is to determine the venison quality from farmed deer according to cuts or muscles based on fatty acid profiles and cholesterol content and to do comparative study on venison quality between species of farmed deer (rusa, sambar, fallow and imported red deer) and feeding regimens, i.e., grass-fed vs concentrate-fed venison. The samples of venison were derived from javan rusa (*Cervus timorensis russa*), moluccan rusa (*Cervus timorensis moluccensis*), sambar (*Cervus unicolor brookei*), fallow (*Dama dama*) and imported red deer (*Cervus elaphus*). Moluccan rusa and red deer were grass-fed deer. Javan rusa, sambar and fallow deer were concentrate-fed deer. Cholesterol content in *Longissimus Dorsi* (LD) muscles of sambar, fallow and rusa deer were 75.36, 76.61 and 77.58 mg $100g^{-1}$ of fresh venison, respectively. Cholesterol content in *Biceps Femoris* (BF) muscles of moluccan rusa, sambar, fallow and red deer were 56.61, 59.26, 86.37 and 98.44 mg $100g^{-1}$ of fresh venison, respectively. Concentrate-fed deer LD and *Psoas Major* (PM) muscles show higher C18:2 (n-6) than grass-fed deer. Grass-fed rusa deer shows the highest C18:3 (n- 3) percentages in PM muscle. Grass-fed rusa and red deer gave an ideal n-6:n-3 ratio of less than 5. Species of deer did not influence n-6:n-3 ratio and fatty acid composition in venison. Feeding regimens (grass-fed vs concentrate-fed) significantly ($p<0.05$) influence n-6:n-3 ratio, fatty acid profiles and cholesterol content in the venison of farmed deer in this study.

Key words: Venison, farmed deer, fatty acids profiles, cholesterol, grass-fed, concentrate-fed

INTRODUCTION

The most important factors influencing the changes in consumer demand for meat and meat products are: (Resurreccion, 2003) increased health concerns, change in demographic characteristics, the need for convenience and increased eating away from home, change in distribution and change in relative prices. As a result of the changes in the demand for meat, interest in new red meat products such as venison which claimed to be low-fat red meat and particularly convenience-oriented products, has dramatically increased in recent years (Drew, 1985). An emphasis on nutrition and health, mainly diet, saturated fat, cholesterol and obesity by consumers in the developed countries have changed the demand for food products, especially meats (Simopoulos, 1999). Health conscious consumers associate diet with the probability of experiencing health problems or diseases such as high blood pressure, cancer and heart disease. Increased health concerns have resulted in a shift away from high-fat, high-protein diets to a trend of more fresh vegetables and fruits in their diet. Veal, beef, pork and lamb, on the other hand, have experienced significant declines in consumption over the same period (Wood *et al*., 2003).

Nutritional concerns about fat and cholesterol have encouraged production of leaner animals, lower-fat ground meat and processed meat products. There has been an increased interest in recent years in ways to manipulate the fatty acid composition of meat. This is because meat is seen to be a major source of fat in the diet and especially of saturated fatty acids, which have been implicated in diseases associated with modern life, especially in developed countries.

More recently, nutritionists have focused on the type of Polyunsaturated Fatty Acids (PUFA) and balance in diet between omega-3 (n-3) PUFA formed from alpha-linolenic acid (18:3) and omega-6 (n-6) PUFA formed from linoleic acid (18:2) (Williams, 2000). Essential Fatty Acids (EFAs) are polyunsaturated and grouped into two families, the omega-6 EFAs and the omega-3 EFAs. The metabolic products of omega-6 acids promote inflammation, blood clotting and tumor growth, the omega-3 acids act entirely opposite (Simopoulos, 1996). It

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is important to maintain a balance of omega-3 and omega-6 in the diet as these two substances work together to promote health (Simopoulos, 2002). The ratio of n-6:n-3 PUFA is also a risk factor in cancers and coronary heart disease, especially the formation of blood clots leading to heart attack (Enser, 2001). The recommendation is for a ratio of less than 5 and again some meats are higher than this (Simopoulos and Robinson, 1998). Meat from grass-fed animals is often higher in n-3 than meat from the corresponding grain-fed animal (Larick and Turner, 1990; Wood *et al*., 1999).

Variations in fatty acid composition explain some of the quality differences between muscles in shelf life and flavor (Mitchell *et al*., 1991; Wood *et al*., 2004). The fatty acid composition of ruminant meats can have an influence on meat flavor, along with other important quality attributes and this is very much influenced by the diet given to the animal (Wood *et al*., 1999; Sanudo *et al*., 2000). It has been reported that animals fed a high-grain or concentrate diet had muscles containing higher concentrations of n-6 PUFA and produced a different flavor profile; while those fed on grass diets had muscles with increased n-3 PUFA concentration (Larick and Turner, 1990). Payne (1978) reported some results on tissue phospholipids in farmed red deer that they were similar in composition to cattle and sheep in most cases except for higher level of linolenic acid. In addition, fatty acids of meat from young red deer that grass-fed deer have high linolenic acid values which are almost certainly due to the shorter retention time of feed in the rumen of deer compared with animals such as sheep (Timothy and David, 1979). Domestic beef obtained under modern agricultural condition contains very small or practically undetectable amounts of alpha-linolenic acid (LNA). On the other hand, deer that forage on ferns and mosses contain more omega-3 fatty acids (LNA) in their meat (Simopoulos, 1996).

So far, little study has been performed to investigate the quality in term of fatty acid profiles, n-6:n-3 PUFA ratio and cholesterol content of venison from grass-fed and concentrate-fed farmed deer in the tropic. It is important to evaluate venison characteristics as a new high quality red meat in the meat marketing system. This information is vital to ensure their commercial success and dietary benefits. Thus, the objectives of this study are to determine the venison quality from farmed deer according to cuts or muscles based on fatty acid profiles and cholesterol content and to do comparative study on venison quality between species of farmed deer (rusa, sambar, fallow and imported red deer) and feeding regimens, i.e., grass-fed versus concentrate-fed venison.

MATERIALS AND METHODS

Venison sources and sample preparation: Five different sources of venison were selected in this study (Table 1). Javan rusa deer (*Cervus timorensis russa*) samples (n = 6) were from Sungei Buloh Farm (deer were grass-fed plus high concentrate diets at approximately 0.5 kg DM/day/head of commercial deer pellet on semi-intensive system). Moluccan rusa deer (*Cervus timorensis moluccensis*) samples (n = 6) were from Arab-Malaysia Agriculture Farm (deer were grass-fed on open pasture grazing system). Sambar deer (*Cervus unicolor brookei*) samples (n = 3) were from UPM Bio-park (deer were fed on cut grasses and high concentrate diets at approximately 1 kg DM/day/head of commercial deer pellet in confinement-raised system) (Dahlan and Jiwan, 2003). Fallow deer (*Dama dama*) samples (n = 5) were from Private Deer Farm (deer were fed on cut grasses and concentrate diets at approximately 0.5 kg DM/day/head of commercial deer pellet in confinement-raised system). Red deer (*Cervus elaphus*) samples (n = 5) were obtained from local meat purveyors (imported venison from New Zealand-Pasture-raised animals). Corbett (2001) mentions that deer production in Australia and New Zealand is primarily from pasture grazing system.

All samples of venison used in the formed of primal cuts (Dohlan, 2000) round, saddle or loin, sirloin, rump, ribs, shoulder and shank were used in cholesterol and fatty acids analysis. Major muscles from each primal cut were separated, wrapped with aluminium foil and packaged in plastic bags and labeled and kept in freezer at- 20°C for 3 weeks before each analysis were carried out. Selected muscle samples were *Biceps Femoris* m. (BF), *Semitendinosus* m. (ST) and *Semimembranosus* m. (SM) from round cuts, *Longissimus Dorsi* m.(LD) from saddle cuts, *Psoas Major* m. (PM) from sirloin cuts, *Gluteus Medius* m. (GM) from rump cuts, LD from ribs cuts, *Infraspinatus* m. (IS) from shoulder cuts and BF from hind shank cuts. Each meat sample was thawed at 4°C in the chiller for 24 h before further analysis.

Cholesterol analysis: Cholesterol was analyzed using Gas Chromatography (GC) on unsaponified fat extracted from the meat samples (Wang *et al*., 1994). Add 25 mL KOH reagent and anti-bumping granules into the extracted matter in test tube on hot plate. Use reflux chamber and heat the mixture at 95-100°C for 30 min. Add 15 mL water into the test tube after boiling stop (5-10 min). Pour the test tube content into 250 mL separating funnel. Wash and add 10 mL water into the test tube, shake slowly and pour into separating funnel. Add 20 mL hexane into the

Table 1: Sources of venison samples, deer species and feeding management

Source	n	Deer species	Feeding management
Sungei buloh farm	6	Rusa Javan (*Cervus timorensis*)	Semi-intensive management (cut grass and concentrate@ feeding)
A-malaysia agric	6	Rusa moluccan (*Cervus timorensis*)	Open grazing management (pasture-grass feeding)
UPM Biopark	3	Sambar deer (*Cervus unicolor brookei*)	Confinement management (cut grass and concentrate@ feeding)
Imported venison (New Zealand)	5	Red deer (*Cervus elaphus*)	Open grazing management (pasture-grass feeding).
Private local farm	5	Fallow (*Dama dama*)	Semi-intensive management (grazing plus concentrate@ feeding)

@ Commercial deer pellet (crude protein = 180 – 200 g kg^{-1} DM, ME = 10 – 12 MJ kg^{-1} DM)

tube and mix slowly and pour into separating funnel. Repeat the steps up to total of 50 mL hexane added to the content and collect unsaponified matter in the separating funnel. Let the solution form 2 layers in the funnel and collect the soap solution. Repeat the steps by using 25 mL hexane for the extraction of unsaponified matter. Evaporate the hexane using rotary evaporator. Transfer unsaponified matter into vial and wash with hexane or petroleum ether. Evaporate the solvent by using N_2 blow. Standard preparation: Dissolve standard (cholestane) in Dichloromethanol (DCM) and determine its content. Standard supplied by Sigma Chemical Co. and its purity is 97.7%. Weigh exactly 0.1 g cholestane into 50 mL volumetric flask and dissolve with DCM up to the mark.

Sample preparation: Dissolve weighted unsaponified matter with DCM. Add DCM up to the mark in 5 mL volumetric flask. Mix cholestane with the sample as internal standard and make it into 500 μL cholestane solution and put it into 2 mL volumetric flask. Inject 2 μL sample solution to GC.

The samples were then analyzed by capillary GC (Hewlett-Packard 5890 series 11 with Hewlett-Packard 3396A Integrator) using split injector (split ratio 100: 1), helium conductor gas was used at flow rate of 25 cm s^{-1} and SAC-5 capillary column (30m×0.25 mm×0.25 μm (pore size); Supelco sp-2330) with a flame ionization detector. The oven temperature was programmed from 250 to 300°C at 5°C min^{-1}, with the injector port temperature at 300°C and the detector temperature at 310°C. Total run time was 25-30 min.

Calculation of cholesterol content: Cholesterol peaks were identified from chromatogram. Peak area of cholestane (known) was compared with tested samples or Response Factor (RF);

Amount of cholesterol per injection;

$$P(\mu g)=\frac{(RF\times \text{cholesterol peak area})\times (\text{Amount of cholestance}(\mu g))}{(\text{Cholestance peak area})}$$

Amount of cholesterol in unsaponified matter = P x dilution factor = Q μg

$$\text{Amount of cholesterol in 100 g venison} = \frac{Q \times (\%\ \text{Lipid in venison})}{\text{Amount of lipid for cholesterol analysis (g)}}$$

Fatty acids analysis: Fatty acids were determined using methylation method. About 50 μL extracted lipid put in the test tube for reflux. Add 1 mL toluene and 2 mL acidified methanol. Test tube was attached to condenser, heated and reflux at 80°C for 2 h. Add 5 mL NaCl to stop the reaction. Transfer the content to 12 mL test tube. Add 3 mL hexane. Mix and centrifuge at 2500 rpm for 5 min. Remove hexane from test tube. Repeat extraction by using 2 mL hexane. Add $KHCO_3$ to maximum capacity. pH should be > 6.5. Shake and centrifuge, remove hexane at top layer into vial and condense the hexane in vacuum or keep it under nitrogen blanket. Reconstitute with 70-100 μL Chloroform. Extracted lipid is ready for a gas chromatograph analysis. The fatty acid profiles were determined with a gas chromatograph (Perkin Elmer Auto System with Turbochrom software), equipped with a Flame Ionization Detector (FID). One microliter of fatty acid solution was injected into capillary column (Stable wax column, 30 m×0.32 mm (internal diameter) × 0.25 μm (pore size) (Restek Co.). Helium was used as the conductor gas at a flow rate of 18.0 cm s^{-1}. The split relationship was 100:1. The operating conditions of the gas chromatograph were as follows: the initial temperature was maintained at 150°C for 5 min, with a programmed increase 230°C at a rate 5°C min^{-1}, with a final 5 min hold period. Total run time was 21 min. The injector and detector temperatures were 210 and 250°C, respectively. The fatty acid peaks were identified via comparison with retention times of fatty acid methylester standards. Results were expressed as percentages of the total fatty acid detected based on the total peak area.

Statistical analysis: All data were analyzed using General Linear Model Procedure (SAS, 1989). Means were

compared by using Duncan's Multiple Range Test. Standard deviation, standard error and significant level were reported.

RESULTS AND DISCUSSION

Cholesterol content of venison: Table 2 shows cholesterol content of LD and BF muscles of fallow, rusa, sambar and red deer. The result showed that cholesterol content of BF muscles from grazing rusa and sambar were significantly lower ($p<0.001$) than fallow and red deer. Red deer BF muscles have the highest ($p<0.05$) cholesterol content than other species. Cholesterol content in LD muscles of sambar, fallow and rusa deer were 75.36, 76.61 and 77.58 mg 100 g^{-1} of fresh venison, respectively. Cholesterol content in BF muscles of moluccan rusa, sambar, fallow and red deer were 56.61, 59.26, 86.37 and 98.44 mg 100 g^{-1} of resh venison, respectively. Drew *et al.* (1991) recorded that the cholesterol content of fresh loin and leg muscles of red deer were 66 and 74 mg $100g^{-1}$, respectively. This study showed that farmed deer venison in Malaysia showed similar range of cholesterol content to New Zealand farmed deer.

Fatty acid profiles of venison: Fatty acid composition of LD and PM muscles of farmed deer are shown in Table 3. The result showed that C16:0 (palmitic acid) is the highest Saturated Fatty Acid (SFA) found in all muscles of farmed deer. C16:0 fatty acid was the lowest (23.9%) in concentrate-fed javan rusa LD muscles and C16:0 fatty acid was the highest (34.3%) in grass-fed moluccan rusa LD muscles. Oleic acid, C18:1(n-9); monounsaturated fatty acid was the highest Unsaturated Fatty Acid (USFA) found in both LD and PM muscles of all deer. Long chain

Table 2: Cholesterol content (mg 100 g^{-1} dry sample) of *longissimus dorsi* and *biceps femoris* muscles of fallow, sambar, rusa and red deer

Muscles	Species	n	Mean	S.D^{+}	Significant level
*Longissimus dorsi**	Sambar	3	101.30^{a}	0.39	
	Fallow	5	103.17^{b}	0.62	p<0.05
	Rusa Javan	6	104.25^{b}	0.10	
*Biceps femoris***	Rusa Moluccan	6	75.63^{a}	0.44	
	Sambar	3	79.52^{b}	0.21	p<0.001
	Fallow	5	115.83^{c}	0.43	
	Red deer	5	139.40^{d}	0.34	

* Samples were taken from saddle cuts of each species, **Samples were taken from round cuts of each species, $^{+}$S.D-Standard Deviation

Table 3: Fatty acid profiles of *Longissimus dorsi* and *Psoas major* muscles of farmed deer

Fatty acids	*Longissimus dorsi*				*Psoas major*		
	Rusa J	Rusa M	Fallow	Sambar	Rusa J	Rusa M	Fallow
C10:0	0.25	-	0.76	0.92	1.11	1.30	0.64
C12:0	0.22	0.34	-	-	0.25	-	0.27
C14:0	6.56	9.87	6.99	3.19	7.15	5.49	8.26
C14:1	3.10	3.38	4.43	1.58	2.74	1.40	3.68
C15:0	0.55	0.72	0.58	0.88	0.65	0.75	0.70
C15:1	1.24	1.09	1.27	1.61	1.38	4.16	1.27
C16:0	23.91	34.27	30.30	26.98	26.12	27.98	31.12
C16:1(n-7)	8.90	11.25	15.03	12.57	8.37	6.89	12.18
C16:1(n-9)	0.57	0.89	1.55	0.41	0.51	-	0.96
C17:0	0.33	0.46	-	0.60	0.39	0.67	-
C17:1	0.71	0.71	-1.39	1.18	2.01	-	
C18:0	16.22	7.55	8.25	12.62	15.63	14.00	10.15
C18:1(n-9)	22.96	17.03	21.97	20.10	22.03	22.10	19.94
C18:2(n-6)*	6.61	1.45	3.43	8.91	6.48	5.96	3.61
C18:3(n-3)**	0.32	0.28	0.35	0.36	0.34	1.17	0.46
C20:0	0.15	-	-	-	-	-	-
C20:4	2.86	1.59	1.54	3.10	2.82	3.03	1.73
C22:1	-	0.38	-	-	-	-	-
Total	95.46	91.06	96.45	95.22	97.15	96.91	94.97
Others	4.54	8.94	3.55	4.78	2.85	3.09	5.03
SFA	48.19	53.21	46.88	45.19	35.67	50.19	51.14
USFA	47.27	38.05	49.57	50.03	45.84	46.72	43.83
PUFA	9.79	3.32	5.32	12.37	9.64	10.16	5.80
PUFA: SFA	0.20	0.06	0.11	0.27	0.27	0.20	0.11
Ratio n-6:n-3	20.66	5.18	9.80	24.75	19.06	5.09	7.85

*C18:2 (n-6)-linoleic acid (omega-6 fatty acid, ω-6), **C18:3(n-3) -linolenic acid (omega-3 fatty acid, ω-3), C12:0 – Lauric acid; C16:0 – Palmitic acid; C16:1(n-7)-Palmitoleic acid; C18:0-Stearic acid; C18:1(n-9)-Oleic acid; C20:0-Arachidic acid; C20:4-Arachidonic acid; C22:1-Erucic acid, SFA-Saturated Fatty Acids; USFA-Unsaturated Fatty Acids; PUFA-Polyunsaturated Fatty Acids, Rusa J-Rusa Javan (grass + concentrate-fed deer), Rusa M-Rusa Moluccan (grass-fed deer)

Table 4: Fatty acid profiles of *Semitendinosus* (ST), *Semimembranosus* (SM) and *Biceps Femoris* (BF) muscles of farmed deer

Fatty acids	Rusa deer				Fallow	Sambar	Red deer
(%)	Bfj*	Stm**	Smm@	BFm#	BF	BF	BF
C10:0	0.22	-	0.83	0.44	0.87	0.67	1.23
C12:0	0.15	-	-	-	-	0.28	-
C14:0	5.82	5.60	6.95	5.87	6.98	2.79	3.68
C14:1	4.81	2.52	3.16	2.28	6.81	1.47	0.30
C15:0	0.57	-	0.63	0.66	0.60	0.81	1.89
C15:1	1.38	2.82	2.94	2.10	1.16	1.29	6.30
C16:0	24.07	26.57	29.27	24.51	27.06	26.81	27.64
C16:1(n-7)	15.05	11.01	12.53	8.87	21.10	14.42	2.11
C16:1(n-9)	1.17	-	1.10	0.73	1.91	0.35	0.65
C17:0	0.26	-	0.43	0.51	-	0.50	1.74
C17:1	0.45	3.01	0.79	1.14	-	1.25	2.34
C18:0	8.89	11.75	8.71	9.78	4.77	11.65	22.78
C18:1(n-9)	22.20	23.73	21.20	20.51	19.36	23.11	19.85
C18:2(n-6)	5.89	5.70	3.80	3.90	2.10	8.72	3.03
C18:3(n-3)	0.29	1.00	0.53	0.82	0.30	0.43	1.40
C20:0	0.10	-	-	-	-	-	0.31
C20:4	3.34	2.13	2.28	4.77	1.42	2.85	0.75
C22:0	0.09	-	-	-	-	-	-
Total	94.75	95.84	95.15	86.89	94.98	97.40	96.00
Others	5.25	5.16	4.85	13.11	5.02	2.60	4.00
SFA	40.17	43.92	46.82	41.77	40.28	43.51	59.27
USFA	54.58		51.92	48.33	45.12	54.16	53. 8 9
	36.73						
PUFA	9.52	8.83	6.61	9.49	3.82	12.00	5.18
PUFA: SFA	0.24	0.20	0.14	0.23	0.10	0.28	0.09
Ratio n-6:n-3	20.31	5.70	7.17	4.76	7.00	20.28	2.16

**Biceps femoris* muscle of Rusa Javan, ** *Semitendinosus* muscle of Rusa Moluccan, @*Semimembranosus* muscle of Rusa Moluccan, #*Biceps femoris* muscle of Rusa Moluccan

Table 5: Fatty acid profiles of primal cuts from farmed rusa deer

Fatty acids	Primal cuts+						
(%)	Rump*	Rump+	Ribs+	Sirloin+	Round+	Saddle+	Shoulder+
C10:0	0.52	-	-	-	0.71	-	0.19
C12:0	-	-	0.30	-	-	-	0.29
C14:0	4.62	4.75	9.55	9.19	7.65	7.78	7.67
C14:1	2.43	2.11	2.04	1.66	1.96	1.98	1.56
C15:0	0.79	0.59	0.94	0.99	0.82	0.76	0.95
C15:1	1.22	3.42	1.22	1.30	2.71	1.84	0.89
C16:0	22.33	26.26	32.00	33.27	30.09	29.40	31.12
C16:1(n-7)	8.40	11.57	6.94	6.31	7.87	7.55	6.59
C16:1(n-9)	0.53	0.95	0.58	0.51	-	0.60	0.49
C17:0	0.67	0.47	0.78	0.87	0.72	0.67	0.88
C17:1	1.04	1.54	0.32	0.72	1.36	1.17	0.95
C18:0	14.17	10.15	13.70	16.45	13.74	12.89	15.47
C18:1(n-9)	23.35	24.37	25.02	22.44	25.40	22.55	24.42
C18:2(n-6)	7.63	5.85	1.83	2.23	3.37	2.85	1.76
C18:3(n-3)	0.70	1.14	0.41	0.50	0.72	0.64	0.42
C20:0	0.22	-	-	-	-	-	0.19
C20:4	4.02	3.01	0.84	1.13	1.95	1.73	0.73
Total	92.64	96.18	96.47	97.57	99.07	94.57	91.26
Others	7.36	3.82	3.53	2.43	0.93	7.59	5.43
FA	43.32	42.22	57.27	60.77	53.73	51.50	56.76
USFA	49.32	53.96	39.20	36.80	45.34	40.91	37.81
PUFA	12.35	10.00	3.08	3.86	6.04	5.22	2.91
PUFA: SFA	0.29	0.24	0.05	0.06	0.11	0.10	0.05
Ratio n-6:n-3	10.90	5.13	4.46	4.46	4.68	4.45	4.19

**Gluteus medius* muscles of Rusa Javan (n = 6), +primal cuts/muscles of Rusa Moluccan (n = 6); Rump-*G. medius* m., Ribs-*L. dorsi* m., Sirloin-P, *major* m., Round-*B. femoris* m., Saddle/loin-*L. dorsi* m., Shoulder-*Infraspinatus* m

SFA C18:0 (stearic acid) was found higher in LD muscles of concentrate-fed deer i.e., javan rusa and sambar deer than grass-fed moluccan rusa and fallow deer. C18:0 was higher in PM muscles of both rusa and fallow deer. Concentrate-fed deer LD and PM muscles show higher C18:2(n-6) linoleic acid than grass-fed deer. Grass-fed rusa deer shows the highest C18:3 (n-3) linolenic acid percentage (1.2%) in PM muscles than other deer species.

Grass-fed rusa deer shows the lowest C18:2 (n-6) than other concentrate-fed rusa, fallow and sambar deer. Total SFA was lower in LD and PM muscles of concentrate-fed rusa, sambar and fallow deer than grass-fed rusa deer. Total USFA was the lowest in LD muscles of grass-fed rusa deer. Total PUFA was highest in LD muscles of sambar deer. Grass-fed rusa deer shows lower n-6:n-3 ratio than concentrate-fed rusa, sambar and fallow deer. Grass-fed rusa deer gave n-6:n-3 ratio values of near 5 for both LD and PM muscles. Concentrate-fed rusa deer gave higher n-6:n-3 ratio values of 19.1 and 20.7 for PM and LD muscles, respectively.

Table 4 shows fatty acid composition of ST, SM and BF muscles of farmed deer. Similar fatty acid profiles were found in these muscles as with LD and PM muscles in this study. C16:0 was the highest SFA found in all muscles and C18:1 (n-9) was the highest USFA found in all deer muscles. Grass-fed rusa and red deer shows higher C18:3 (n-3) than concentrate-fed rusa, sambar and fallow deer. Grass-fed rusa and red deer gave lower n-6:n-3 ratio than concentrate-fed rusa, sambar and fallow. This study showed that grass-fed rusa and red deer gave ideal n-6:n-3 ratio of less than 5. There are differences in PUFA levels in venison, feral deer tend to be higher in PUFA than farmed deer and most of the PUFA is in the phospholipids fractions (Fross *et al*., 1979). Miller *et al.* (1986) shown that the proportion of C18:3, in total PUFA measured were higher in the muscle of deer and range steers than that feedlot steers.

Table 5 shows fatty acid profiles of primal cuts from farmed rusa deer. Rump cuts of concentrate-fed rusa deer show the highest C18:2 (n-6) compositions. Rump cuts of grass-fed rusa deer show the highest C18:3 (n-3) compositions. This study found that the ratio of n-6:n-3 of all grass-fed rusa deer primal cuts were less than 5. Table 6 and 7 show n-6:n-3 ratio between species and muscles of farmed deer. Confinement-raised deer using concentrate diets with or without forage-grass such as javan rusa, sambar and fallow deer showed higher ($p<0.05$) n-6:n-3 ratio than grass-fed or pasture grazing rusa and red deer. Species of deer in this study did not show any significant influence on n-6:n-3 ratio and fatty acid composition in the venison. Feeding regimens showed significant influence on n-6:n-3 ratio, fatty acid and fat composition in the venison. Scientists found that diet can significantly alter fatty acid in ruminants. Cattle fed primarily grass enhanced the n-3 content of beef by 60% and also produces a more favorable n-6:n-3 ratio (Ducket *et al*., 1993; Wood and Enser, 1997). Grass-fed cattle have much higher concentrations of n-3 PUFA (Marmeret *et al*., 1984; Enser, 1998; Cho *et al*., 2005) than concentrate-fed animals, which in turn have higher concentrations of n-6 PUFA. Vatasever *et al.* (2000) stated that n-3 PUFA concentrations in beef were greatly influenced by diet. Although, the fatty acid profile in ruminants is not a direct reflection of the dietary fatty acid composition due to hydrogenation by rumen micro-organisms, some changes in this profile can be attributed to the diet.

Table 6: Omega-6: omega-3 fatty acid ratio between species and muscles of farmed deer

Species	Muscle	Mean*	S.D+	Significant level
Rusa Javan	*L. dorsi*	20.66^{a}	0.02	
(n = 6)	*B. femoris*	20.31^{b}	0.02	
	P. major	19.06^{c}	0.03	
	G. medius	10.90^{d}	0.23	p<0.001
Rusa Moluccan	*L. dorsi*	5.18^{a}	0.03	
(n = 6)	*G. medius*	5.13^{ab}	0.03	
	P. major	5.09^{b}	0.03	
	B. femoris	4.76^{d}	0.03	p<0.001
Fallow	*L. dorsi*	9.80^{a}	0.02	
(n = 5)	*P. major*	7.85^{b}	0.02	
	B. femoris	7.00^{c}	0.09	p<0.001
Sambar	*L. dorsi*	24.75^{a}	0.01	
(n = 3)	*B. femoris*	20.27^{b}	0.10	p<0.001
Red deer	Shank cut	3.83^{a}	0.60	
(n = 5)	*B. femoris*	2.16^{b}	0.02	p<0.01

+S.D-Standard deviation, *Means with similar superscripts within the same deer species are not significantly different (p>0.05)

Table 7: Omega-6: omega-3 fatty acid ratio between deer species within similar muscles (*L.dorsi, p. major, b. femoris and g. medius*)

Muscle	Species	Mean	S.D+	Significant level
L.dorsi	Sambar	24.75^{a}	0.01	
	Rusa Javan	20.66^{a}	0.01	
	Fallow	9.80^{c}	0.01	
	Rusa Moluccan	5.18^{d}	0.02	p<0.001
P. major	Rusa Javan	19.06^{a}	0.02	
	Fallow	7.85^{b}	0.01	
	Rusa Moluccan	5.09^{c}	0.01	p<0.001
B. femoris	Rusa Javan	20.31^{a}	0.01	
	Sambar	20.27^{a}	0.06	
	Fallow	7.00^{b}	0.05	
	Rusa Moluccan	4.76^{c}	0.02	
	Red deer	2.16^{d}	0.01	p<0.001
G. medius	Rusa Javan	10.91^{a}	0.14	
	Rusa Moluccan	5.13^{b}	0.02	p<0.001

+S.D.-Standard deviation, $^{a-d}$Means with similar superscripts within the same muscle type are not significantly different (p>0.05)

CONCLUSION

Cholesterol content in venison was not affected by feeding regimens found in this study. Rusa and sambar deer significantly showed lower cholesterol content in the venison than fallow and red deer. Cholesterol content in LD muscles of rusa, sambar and fallow deer were 75.36, 76.61 and 77.58 mg $100g^{-1}$ of fresh venison, respectively. This study showed that farmed deer in Malaysia showed similar range of cholesterol content in the venison to New Zealand farmed deer.

Fatty acid profiles of venison from farmed deer showed that palmitic acid (C16:0) was the highest SFA found in all venison samples. C16:0 was the highest in grass-fed rusa deer. C18:0 was found higher in concentrate-fed than grass-fed deer. C18:2 PUFA was higher in concentrate-fed deer. C18:3 PUFA was the highest in grass-fed deer. This study also showed that SFA was found lower in concentrate-fed than grass-fed deer and USFA was lower in grass-fed deer. The important finding of this study is n-6:n-3 ratio was lower in grass-fed than concentrate-fed deer and the ratio was near 'ideal' value of 5. This study concluded that species of deer did not show obvious influence on n-6:n-3 ratio and fatty acid composition in the venison. Feeding regimens (grass-fed vs concentrate-fed) did show significant influence on n-6:n-3 ratio, fatty acid and fat composition in the venison of all farmed deer species in this study.

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