Journal of Animal and Veterinary Advances 5(5) : 364-372, 2006

Feed Intake and Weight Gain of Lambs of the Fiji Fantastic Sheep Fed Concentrate Mixtures of Varying Energy and Protein Levels

[1]Rokomatu, I., [1]E.M. Aregheore and [2]P. Manueli
[1]Department of Animal Science, The University of the South Pacific, School of Agriculture, Alafua Campus Apia, Samoa
[2]Secretariat of the Pacific Community (SPC) Animal health and Production Division Private Mail Bag, Suva, Fiji

Abstract: Thirty lambs (15 rams and 15 ewes), 4-5 m old, pre-experimental mean body weight of 20.9±0.5 kg were divided into five treatment groups of six lambs each, (3 ewes and 3 rams) in 2x5 factorial randomized complete design experiment. These were used to investigate the effects of concentrate mixtures of varying energy and protein levels on voluntary feed intake, growth rate and nutrient utilization for 84 experimental days. The five concentrate mixtures were designated as HPHE; HPME; HPLE; MPME and LPME. First letter in each concentrate mixture designates protein level while the third letter designates energy level (H, high, M, medium and L, low). The letters P and E stands for protein and energy, respectively. CP and GE content of HPHE, HPME, HPLE, MPME and LPME concentrate mixtures were 16.5, 16.5, 16.5, 15.0 and 13.0%; 21.6, 19.0; 17.6 and 19.0 MJ/kg, respectively. Significant differences ($p<0.001$) were observed among lambs in DMI of concentrate mixtures. Lambs on HPLE had higher concentrate intake (467 g) while lambs on HPHE were lowest at 357 g/head/day. Total DMI (concentrate + forage) was significantly different ($p<0.001$) for lambs in the different treatments. Sex has no significant effect ($p<0.05$) on DMI. ADG of ram lambs were 83, 140, 117, 131 and 81 compared to 81, 101, 101, 91 and 79 g/d for ewe lambs, respectively on HPHE; HPME, HPLE, MPME and LPME concentrate mixtures and these were significantly different ($p<0.05$). ADG was numerically higher in ram lambs on MPME and HPHE and lowest on LPME. Better-feed efficiency was obtained in lambs on HPME, MPME and HPLE treatments. Daily protein intake was significantly different ($p<0.001$) among lambs in the different treatments. Blood urea-N and blood glucose concentration in lambs on HPHE, HPME, HPLE, MPME and LPME concentrate mixtures significantly increased ($p<0.001$) at the post experimental period. Treatments and sex had significant effects on nutrients digestibility and rams were higher than ewes in the digestibility of DM, OM, CP, ADF, ADL and hemicellulose ($p<0.001$). Sex and dietary treatments have influence on DMI, nutrient digestibility and growth rate of lambs. Based on all parameters tested, available data therefore demonstrate that dietary CP that ranged between 15 to 16.5 % CP (daily protein intake of 6.8-7.7 g/kg $^{0.75}$/day); and 17.6 to 19.0 MJ GE/kg BW (10.9-11.8 digestible energy KJ/kg DM), respectively will satisfy the requirements of ewe and ram lambs of the Fiji Fantastic sheep for maximum growth in the tropical environment of Fiji. In conclusion all the treatments with the exception of the LPME concentrate mixture are likely to ensure adequate supply of available nutrients and energy for rumen degradation. However, the HPME treatment that had 16.5% CP (daily protein intake of 6.8 g/kg $^{0.75}$/day) plus 19.0 MJ GE/kg BW (11.7 digestible energy KJ/kg DM) was the best because the lambs on it had better average live weight gain at 121 g/lamb/d.

Key words: Fed intake, weight gain, lambs, concentrate mixtures, varying energy and protein

INTRODUCTION

The Fiji Fantastic (FF) sheep, originates from the crossbreeding of Wiltshire x Blackbelly Barbados[1]. The breed is well adapted to the dry humid conditions of Fiji and other Island countries in the South Pacific region. FF has the characteristic of naturally shedding its wool and this is an advantage to its survival in the hot and humid weather of Fiji. Besides it has a high lambing rate of over 120%[1].

At present, no data exist on dietary energy and protein requirements and subsequently on nutrient utilization of the Fiji Fantastic sheep[1]; personal communication). Therefore it is difficult to formulate complete diets adequate with respect to all nutrients particularly energy and protein, capable of promoting

Corresponding Author: I. Rokomatu, Department of Animal Science, The University of the South Pacific, School of Agriculture, Alafua Campus Apia, Samoa

good growth and efficient meat production of this sheep. There is still scant data on the feed intake and nutrient utilization of sheep and goats under the traditional and organized systems of production in the South Pacific Island countries..

The extent to which varying levels of dietary energy and protein fed to tropical sheep breeds are utilized for maintenance, growth, reproduction and lactation has been reported[2,3]. Also other researchers have reported on feed intake and nutrient utilization of sheep under tropical conditions[4,5].

Scientific knowledge on the optimal level of nutrient requirements for the commercial production of lambs of the FF sheep is lacking. In view of the above, it is imperative to conduct scientific investigation to elucidate nutritional requirements for growth and development of lambs of the FF sheep under the local environment of Fiji. A nutritional study would assist in the formulation of practical diets adequate to enhance the growth and development of the FF sheep. Presently, the demand for sheep meat (mutton) is on the increase in the Pacific Island countries. The objective of this study therefore was to contribute to knowledge particularly when lambs of the Fiji Fantastic Sheep were fed concentrate mixtures of varying energy and protein levels with a view to determining optimal levels for growth.

MATERIALS AND METHODS

Climatic conditions: This experiment was carried out in the wet season (12th February-8th April 2003) with the following climatic conditions, mean temperature, 31.5°C; mean rainfall, 421.1 mm; and mean relative humidity, 73.8%.

Animals, experimental design and diets: Thirty weaned lambs (fifteen rams and fifteen ewes) between 4-5 months of age and pre-experimental mean body weight of 20.9±0.46 kg were selected. They were divided into five treatment groups of six sheep each, balanced as closely as possible for live-weight with three ewes and three rams in each treatment, arranged in a 2x5 factorial randomized complete design experiment.

Five concentrate mixtures of varying energy and protein levels (Table 1) represented the treatments. The concentrate mixtures were designated as HPHE; HPME; HPLE; MPME and LPME. These mixtures were fed with guinea grass (*Panicum maximum*) as the basal diet for 84 days. First letter in each experimental mixture designates protein level while the third letter designates energy level (H, high, M, medium and L, low). The letters P and E stands for protein and energy, respectively.

Table 1: Percentage composition of the concentrate mixtures

Feed ingredients (%)	(%) DM concentrate mixtures + HPHE	HPME	HPLE	MPME	LPME
Wheat[1]	39.5	18.0	6.5	22.0	29.0
Coconut meal[2]	54.5	50.0	47.0	27.0	0
Mill mix[3]	0.5	26.5	41.0	45.5	64.0
Molasses[4]	3.5	3.5	3.5	3.5	5.0
Premix[5]	1.5	1.5	1.5	1.5	1.5
Salt	0.5	0.5	0.5	0.5	0.5
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
Protein	16.5	16.5	16.5	15.0	13.0
Gross Energy (MJ/Kg)	21.6	19.0	17.6	19.0	19.0

+HPHE = High protein, high energy; HPME = High protein, medium energy; HPLE = High protein, low energy; MPME = Medium protein, medium energy; LPME = Low protein, medium energy. [1]Dry matter, 79.2; crude protein, 13.7; crude fibre, 3.1; ether extract, 1.7; ash, 1.9; gross energy, 13.8 MJ/kg. [2]Dry matter 90%, crude protein 20.4%; crude fibre, 9%; ether extract, 11.7%; energy, 18.0 MJ/kg. [3]Dry matter, 88.0; crude protein, 16.3; crude fibre, 9.5; ether extract, 6.0; ash, 6.4; gross energy 16 MJ/kg. [4]Dry matter, 77.4; crude protein, 3.5, crude fibre, 0; ether extract, 0; ash, 8.9; gross energy 12.6 MJ/kg. [5]ALROC Livestock mineral supplement (ALROC Companies, Australia) contains. Phosphorus 3252 mg/kg; Potassium 3787 mg/kg; Sulphur 1.32%; Calcium 5.30%; Magnesium 2.6%; Iron 1.81 mg/kg; Manganese 344 mg/kg; Copper 20.4 mg/kg; Zinc 52.2 mg/kg; Sodium 3.19%

The forage portion was harvested fresh on a daily basis and chopped with an electric chaff-cutter (Nagan Engineering, Fiji Limited, Ba, Fiji) to 9-10 mm pieces. An adjustment period of 15-days was also allowed the lambs to get used to the treatments and the environment before actual data collection.

Feeding and management: The lambs were housed in individual pens that had wooden slatted floor. Feed and water troughs for individual feeding were provided in each pen. Also attached to each pen was a plastic container for forage. The lambs were fed 1.5 kg concentrate plus 2.0 kg forage (*Panicum maximum*) in two equal portions daily at 0800 and 1800 hrs. Rations offered were either increased or decreased depending on intake. Water was made available to each lamb *ad libitum.* Record of individual feed intake and body weight were kept on a weekly basis. However, only average weights at the beginning and end of the experiment were used to express growth rate. Feed offered but not consumed within 24 hrs period was collected, weighed and sampled for subsequent analysis, the leftover being discarded.

Blood collection: Samples of jugular blood were collected four hours after the morning feeding from each lamb by jugular vein puncture into vaccutainers. Blood samples were collected at three periods, pre-mid- and post-experimental (0, 42th and 84th days).

Blood was allowed to clot at room temperature for approximately 15 min and then placed on ice and later centrifuged (Quantum Scientific PTY Ltd, Queensland, Australia) for 10 min at 1500 g and the supernatant was stored at-80°C until required for analysis.

Digestibility studies: At the end of the growth phase, a digestibility trial was carried out using all lambs. The rams were fitted with harness bags and allowed a 5-day adjustment period before a 7-day collection period. The ewes were housed in special pens with slatted floor covered with a very fine wire netting that allows only urine to pass through. A dustpan and brush were used to collect the faeces for 7 days.

The total daily faecal output of lambs was weighed and a 25% sample was removed for dry matter determination. Faeces collected over the period, were oven dried at 70°C for 36 hrs. Daily samples of faeces, concentrate mixtures and forage were bulked separately and milled with a simple laboratory mill (Christy and Norris; process Engineers, Chelmsford, UK) to pass through a 1.7-mm sieve and stored until required for chemical analysis. Apparent nutrients digestibility coefficients were calculated by difference following the procedure of Crampton[6] for mixed diets. Metabolizable energy intake was calculated as Digestible Energy (DE) x0.82[7]. Nutrients and energy digestibility of the guinea grass (*Panicum maximum)* used were DM, 55.0%; OM, 57.1%; CP, 55.0%; NDF, 68.5%; ADF, 66.6%; hemicellulose, 69.9% and energy 53.0% (Aregheore and Rokomatu, 2004).

Analytical procedures: AOAC[8] methods were used to determine nutrient contents in the concentrate mixtures, forage and faecal samples. Fibre fractions, NDF, ADF, ADL, cellulose and hemicellulose were determined using procedures of Van Soest *et al.*[9]. Gross energy (MJ/kg) values of feedstuffs, concentrate mixtures, forage and faecal samples were determined in a bomb calorimeter (Adiabatic bomb, Parr Instrument Co., Moline, IL) using thermo chemical benzoic acid as standard. All analyses were done in triplicate. Serum was analyzed for blood urea-N (BUN) using the methods of Fawcett and Scott[10], while glucose concentration was estimated by a colorimetric assay based on the use of hexokinase and glucose-6-phosphate dehydrogenase (G-6-PD)[11].

Statistical analysis: Experimental data were analyzed using two-way analysis of variance (ANOVA) for factorial randomized complete design with dietary treatments and sex. Where there was no significant difference for sex and interaction between sex and dietary treatments, data for both rams and ewes were pooled and analyzed by one-way analysis of variance (ANOVA) for factorial randomized complete design with MINITAB statistical software[12]. Where significant differences occurred, treatment means were compared by Duncan's multiple range test. Also data on growth, feed intake, blood metabolites and apparent digestibility between ewes and rams within treatments were subjected to student's t-test.

RESULTS

Proximate chemical composition of experimental diet: The chemical composition of the experimental diets is presented in Table 2. The proximate chemical composition (g100 g as fed) of the basal diet of guinea grass (*Panicum maximum)* was DM; 30.3%, CP; 12.8%, ash; 11.3%, NDF; 37.5%, ADF; 25.0%, ADL; 12.0, hemicellulose; 12.5%, OM; 88.8% and gross energy 15.5 (MJ/kgDM).

Dry Matter intake, average daily gain, water intake and daily protein intake: Table 3 presents performance characteristics of sheep on the different treatments. Forage Dry Matter Intake (DMI) was significantly different ($p<0.001$) among treatments with values of 314, 285, 268, 323 and 267 g/head/d for lambs on HPHE, HPME, HPLE, MPME and LPME, respectively. However there was no significant difference ($p>0.05$) between ewes and rams within treatments in forage dry matter intake.

There was also a significant effect of dietary treatments and sex ($p<0.001$) on concentrate DMI. Sheep on HPLE had higher intake of concentrate DM (467 g) while those fed on HPHE were lowest at 357 g/head/day. Total DM intake (forage + concentrate mixture) was significantly ($p<0.001$) different among the treatments and it followed the trend of concentrate DM intake. However, voluntary dry matter intake expressed on a metabolic weight basis was not significantly different ($p>0.001$) among sheep in the different treatments. Between ewes and rams within treatments there were slight differences in concentrate DMI, total DMI and voluntary DMI expressed on a metabolic weight basis but the differences were statistically significant ($p>0.05$).

Average Daily Gain (ADG) of lambs in the different treatments were significantly ($p>0.05$) different from each other and, lambs on HPME treatment had more ADG followed by the lambs on MPME and HPLE, while lambs

Table 2: Proximate chemical composition of the concentrate mixtures

	Concentrate mixtures+				
Nutrients	HPHE	HPME	HPLE	MPME	LPME
Dry matter (DM),(%)	74.3	69.3	68.2	67.3	55.1
Analysis on DM basis					
Crude protein,(%)	16.5	16.5	16.5	15.0	13.0
Ash,(%)	4.3	4.8	5.7	5.6	4.2
Neutral detergent fibre,(%)	42.5	39.1	36.9	31.5	22.4
Acid detergent fibre,(%)	15.8	15.4	15.1	12.1	8.2
Acid detergent lignin,(%)	10.8	10.3	9.9	6.9	2.3
Hemicellulose,(%)	26.7	23.7	21.9	19.3	14.3
Organic matter,(%)	95.7	95.2	94.3	94.4	95.8
Gross Energy (MJ/Kg)	21.6	19.0	17.6	19.0	19.0

+HPHE-High protein, high energy; HPME-High protein, medium energy; HPLE-High protein, low energy; MPME-Medium protein, medium energy; and LPME-Low protein, medium energy Sed-standard error of difference

Table 3: Performance characteristics of sheep on the experimental diets

Parameters	Sex	Concentrate mixtures+ HPHE	HPME	HPLE	MPME	LPME	sem	Sign.
Number of lambs		6	6	6	6	6		
Initial live weight (kg)	Ewes	22.5	21.3	20.5	21.2	20.0		
	Rams	22.2	20.0	20.7	22.0	20.0		
	Mean	22.2	20.4	20.7	21.6	20.0	0.46	n.s
Final live weight (kg)	Ewes	29.3	29.8	29.0	28.8	26.7		
	Rams	29.1	31.8	30.7	33.0	26.8		
	Mean	29.1	30.8	29.8	30.9	26.8	1.35	n.s
Average live weight gain (kg)	Ewes	6.8	8.5	8.5	7.6	6.7		
	Rams	6.9	11.8	9.8	11.0	6.8		
	Mean	6.9	10.2	9.3	9.3	6.8	0.45	n.s
Average daily gain (g)	Ewes	81	101	101	91	79		
	Rams	83	140	117	131	81		
	Mean	82	121	109	111	80	26.6	**
Forage intake (g)	Ewes	314	281	270	317	262		
	Rams	313	288	265	328	272		
	Mean	314	285	268	323	267	30.5	***
Concentrate intake (g)	Ewes	360	409	462	387	376		
	Rams	353	376	472	384	372		
	Mean	357	393	467	386	374	93.6	***
Total dry matter intake (DMI) (g)	Ewes	674	690	732	704	638		
	Rams	666	664	737	712	644		
	Mean	670	677	735	708	641	105.0	***
Percentage of forage in total DMI	Ewes	47	41	37	45	41		
	Rams	47	43	36	46	42		
	Mean	47	42	37	46	42	-	-
Dry matter intake (g/kg$^{0.75}$/day)	Ewes	41.2	43.1	45.7	43.3	21.9		
	Rams	48.7	46.4	42.1	37.8	19.6		
	Mean	44.9	44.8	43.9	40.6	20.8	9.2	***
Water intake (g)	Ewes	807	773	775	863	691b		
	Rams	705	694	729	865	934a		
	Mean	756	734	752	864	812	23.0	n.s
Daily protein (N x6.25)	Ewes	9.9	10.8	11.2	9.2	5.7		
intake (g/kg$^{0.75}$/day)	Rams	11.5	11.5	10.2	8.1	7.3		
	Mean	10.7	10.8	10.7	8.7	6.5	1.7	***
Feed efficiency	Ewes	8.3	6.8	7.2	7.7	8.1		
(kgDMI/kg liveweight gain)	Rams	8.1	5.5	6.2	5.4	7.9		
	Mean	8.2	6.2	6.7	6.7	8.0	-	-

+HPHE-High protein, high energy; HPME-High protein, medium energy; HPLE High protein, low energy; MPME-Medium protein, medium energy; and LPME-Low protein, medium energy sem-Standard error of mean. Sign.-significant; ns -not significant; a,b-means within each treatment for each variable with different letter differ at **p<0.05; ***(p<0.001) Significant at 5 and 1% level of significance

Table 4: Blood urea-N and blood glucose concentration (mmol/L) at pre, mid and post experimental periods

Period (days)	Sex	Concentrate mixtures+ HPHE	HPME	HPLE	MPME	LPME	sem	Sign.
Blood Urea-N								
Pre	Ewes	5.2	6.5	6.7	6.5	5.7		
	Rams	5.9	6.5	7.2	5.4	5.3		
	Mean	5.6	6.5	7.0	6.0	5.5	0.17	n.s
Mid	Ewes	7.4	8.3	7.3	7.0	5.6		
	Rams	7.8	7.8	7.4	6.0	4.5		
	Mean	7.6	8.0	7.4	6.5	5.0	0.15	***
Post	Ewes	9.7	9.2	10.0	7.3	8.7		
	Ram	10.1	10.6	9.6	8.2	6.9		
	Mean	9.9	9.9	9.8	7.8	7.8	0.27	**
Blood Glucose								
Pre	Ewes	3.1	3.4	3.1	3.3	3.0		
	Rams	3.3	3.5	3.3	3.3	3.2		
	Mean	3.2	3.5	3.2	3.3	3.1	0.01	n.s
Mid	Ewes	3.7	3.5	3.5	3.6	3.3		
	Rams	3.6	4.1	3.5	3.6	3.5		
	Mean	3.7	3.8	3.5	3.6	3.4	0.01	n.s
Post	Ewes	4.3	3.7a	3.7	3.7	3.6		
	Rams	4.5	4.2b	3.7	3.8	3.8		
	Mean	4.4	4.0	3.7	3.8	3.7	0.01	***

+HPHE-High protein, high energy; HPME-High protein, medium energy; HPLE-High protein, low energy; MPME-Medium protein, medium energy; LPME-Low protein, medium energy. Sem-Standard error of mean.lsd-Least significance difference.Sign.-Significant; n.s- not significant; a,b-means within each treatment for each variable with different letter differ at p<0.05; ***(p<0.001); **(p<0.003) Significant at 1 and 0.1% level of significance, respectively

Table 5: Apparent nutrient digestibility coefficients

Nutrients	Sex	Concentrate mixtures+ HPHE	HPME	HPLE	MPME	LPME	sem	Sign.
Dry matter	Ewes	55.5a	62.2a	67.9a	64.3a	49.8a		
	Ram	65.5b	66.9b	61.7b	57.6b	63.9b		
	Mean	60.5	64.5	64.8	61.0	56.9	2.90	***
Organic matter	Ewes	58.4a	65.6	66.6a	66.8	43.1a		
	Rams	67.8b	69.9	60.2b	60.6	56.2b		
	Mean	63.1	67.7	63.4	63.7	49.6	6.75	***
Crude protein	Ewes	60.6a	65.3	68.1a	61.5	43.9		
	Rams	69.5b	69.6	61.9b	54.3	56.9		
	Mean	65.1	67.4	65.0	58.0	50.4	6.79	***
Neutral detergent fibre	Ewes	63.8a	61.9	72.1a	67.9	61.9		
	Rams	71.9b	66.7	66.7b	61.8	70.7		
	Mean	69.4	67.9	69.4	64.8	64.4	4.68	n.s
Acid detergent fibre	Ewes	62.6a	57.6	61.5a	58.5	64.8a		
	Rams	71.0b	62.9	54.1b	50.7	52.9b		
	Mean	66.8	60.2	57.8	54.6	58.9	4.02	**
Acid detergent lignin	Ewes	47.8a	50.1	60.6a	59.9	38.8		
	Rams	59.6b	56.3	50.3b	52.3	42.9		
	Mean	53.7	53.2	55.5	53.2	40.9	5.44	**
Hemicellulose	Ewes	64.5a	64.8	63.5a	73.7	57.2		
	Rams	72.5b	69.2	56.5b	68.8	60.9		
	Mean	68.5	67.0	60.0	71.2	59.05	1.85	**
Energy	Ewes	62.1	58.8	65.5	65.5	48.1		
	Rams	70.7	63.9	59.1	59.1	59.8		
	Mean	66.4	62.3	61.4	62.3	53.9	4.07	n.s
Digestible energy (KJ/kgDM)	Ewes	13.4	11.2	11.5	12.4	9.0		
	Rams	15.3	21.1	10.4	11.2	11.4		
	Mean	14.4	11.7	10.9	11.8	10.3	1.40	***
Metabolizable energy (MJ/kgDM) (DE x 0.82)	Ewes	10.9	9.2	9.4	10.2	7.5		
	Rams	12.5	9.9	8.5	9.2	9.3		
	Mean	11.7	9.6	8.9	9.7	8.4	1.13	***

+HPHE-High protein, high energy; HPME-High protein, medium energy; HPLE-High protein, low energy; MPME-Medium protein, medium energy; LPME-Low protein, medium energy. Sem-Standard error of mean. Sign.-Significant; n.s. not significant; a,b-means within each treatment for each variable with different letter differ at **p<0.05; ***(p<0. 001) Significant at 0.1% level of significance, respectively

on HPHE and LPME had lower ADG. In all diets rams were better in live-weight gain than ewes. Daily protein intake was 10.7, 10.8, 11.2, 9.2 and 5.7 g/kg$^{0.75}$/day for lambs on HPHE, HPME, HPLE, MPME and LPME, respectively. Sex and dietary treatments had significant effects on daily protein intake (p<0.001). Also no significant difference was observed between ewes and rams within treatments in average daily gain.

Feed efficiency of lambs on HPHE, HPME, HPLE, MPME and LPME were 8.2 6.2, 6.7, 6.7 and 8.0, respectively. Lambs on HPME concentrate mixture had the best-feed efficiency (kgDMI/kg live weight gain) compared to other treatments.

Water intake was 756, 734, 752, 864 and 812 l/day for lambs on HPHE, HPME, HPLE, MPME and LPME concentrate mixtures respectively. There was no significant difference (p>0.001) in water intake among lambs in the different concentrate mixtures, however, there was significant difference (p<0.05) between ewes and rams in the LPME concentrate mixture in water intake at 690 l for ewes and 934 l for the rams.

Concentrations of blood urea-N and blood glucose: Blood urea-N concentration at the pre-, mid- and post- experimental periods is presented in Table 4. At the pre-experimental period there was no statistical difference (p>0.03) in the concentration of blood urea-N of lambs in the different treatments. The lambs adjusted to the different concentrate mixtures at the mid-experimental period and blood urea-N concentrations at the post experimental period, were significant different (p<0.001) among lambs in the different treatments. However, there were no significant difference in blood urea-N between ewes and rams within each concentrate mixture at the pre-mid- and post-experimental periods.

At the pre and mid experimental periods blood glucose concentration were not significantly different (p>0.001) among the lambs in the concentrate mixtures (Table 4). However, at the post experimental period there was significant difference (p<0.001) in blood glucose concentration of lambs on HPHE, HPME, HPLE, MPME and LPME treatments. Except at the post experimental period in which significant difference (p<0.05) was observed in blood glucose concentration between ewes and rams in HPME concentrate mixture, there was no significant difference (p>0.05) in blood glucose concentration between ewes and rams within treatments in HPHE, HPLE, MPME and LPME.

Apparent digestibility of nutrients: Nutrient digestibility coefficients of lambs on HPHE, HPME, HPLE, MPME and LPME are presented in Table 5. There were significant differences ($p<0.001$) in the digestibility of Dry Matter (DM), Organic Matter (OM), Crude Protein (CP), Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL) and hemicellulose among lambs in the different treatments. Apparent digestibility coefficient of CP tended to decrease with a decrease in level of CP in the different treatments. Lambs on the LPME concentrate mixture had the lowest DM, OM, CP ADF, ADL and hemicellulose digestibility. However, significant differences ($p<0.05$) were observed between ewes and rams within treatments in the digestibility of DM, OM, CP, NDF, ADF, ADL and hemicellulose.

There was no significant ($p>0.05$) difference in the digestibility of energy between and within ewe and ram lambs in the different treatments. However, significant differences ($p<0.001$) were observed for lambs in the digestible energy content of the concentrate mixtures. Metabolizable energy concentration of the mixtures were also significantly different ($p<0.001$) from each other for lambs on HPHE, HPME, HPLE, MPME and LPME. HPHE had higher ME concentration and lambs on it had higher Digestible Energy Intake (DEI). DEI among the treatments were not statistically significant from each other at 8.42, 7.62, 7.87, 7.94 and 7.27 (DEI, MJ/day) for HPHE, HPME, HPLE, MPME and LPME, respectively.

DISCUSSION

CP and OM represent important classes of nutrients while NDF indicates an index of bulk. The CP and GE contents of the diets were in accord with calculated values. The CP content of the concentrate mixtures at 13.0 to 16.5% were higher than the range suggested by NRC[13] as adequate to meet the growth requirement of growing sheep. The concentrate mixtures had adequate fibre and the NDF fraction was higher than the 25% level suggested by NRC[14] as adequate for rumen function in growing ruminant livestock.

The lambs on the HPHE treatment had lower intake of concentrate mixture and this followed by the lambs on the LPME, consequently forage intake was less in the lambs on HPLE. Total DMI was higher in lambs on HPLE treatment, followed by lambs on MPME while the least was for lambs on LPME. DMI of lambs of the FF sheep was influenced by the concentration of available protein, fibre and energy in the concentrate mixtures. Voluntary DMI is affected by many factors[15] and DMI values of different breeds of sheep vary widely in the literature.

NDF and CP concentrations[16]; and energy (Aregheore *et al.*, 1988) are the most important factors that affect DMI. The low DMI of lambs on the HPHE treatment may be due to either the level of NDF and energy. The level of NDF can limit DMI[17], however, Von Soest[18] opined that NDF is negatively correlated to DMI.

Ruminants on high-energy diets usually consume less to meet their energy requirement for growth and reproduction. Therefore, when a diet is low in energy, there is the tendency for animals to consume more before their requirements for growth and other physiological processes are met. This observation therefore signifies that besides the CP content of a diet other factors also influences ADG.

The daily DMI of lambs on HPHE, HPME, HPLE MPME and LPME ranged between 1.7 to 2.2% of their body weight and this value was similar to mean DMI of 2.8% of body weight reported by Adu and Olaloku[5] for the West African dwarf sheep in Nigeria. However, the DMI of 1.7 to 2.2% for lambs with body weight of 26.8 to 31 kg lambs used in this trial is however lower than ARC[19,13] values for lambs of similar age and live-weight. Also, the low DMI of lambs on the HPHE treatment however, contradicts[20] who reported higher DMI in early-weaned lambs on high protein diets.

Dietary energy and protein should be in equilibrium to obtain reasonable DMI and lambs on HPME, MPME and HPLE treatments provided evidence to support this view. DMI of lambs in this trial are lower than values of 1000 to 1300 g/d, recommended as adequate to meet requirements of growing sheep[13], but were above levels suggested by ARC[19] as adequate for sheep with body weight of 20 to 35 kg.

Average Daily Gain (ADG) was numerically higher in ram lambs on MPME and HPHE and lowest on LPME. ADG of ram lambs were 83, 140, 117, 131 and 81 compared to 81, 101, 101, 91 and 79 g/d for ewe lambs, respectively for HPHE; HPME, HPLE, MPME and LPME concentrate mixtures. Abouheif *et. al.*[21] reported higher growth rate for fat-tailed Najdi ram lambs than comparable ewe lambs of the same age. Aregheore[22] also reported higher growth rate for ram lambs of the blackhead sheep breed in Zambia. Males make higher gain and females slowest although voluntary dry matter intakes were similar between treatments. However, these values are lower than the ADG of 220 to 450g/d (ARC, 1980) and 250 to 300 g/d[13] reported for the same age and live-weight of lambs compared to those used in this trial. Differences between ADG gain of tropical and temperate breeds of sheep are due to several factors amongst which; are environmental conditions, feed quality (protein quality); requirements and genotype[23]. The level and quality of protein plays an important role in ADG.

ADG of lambs on HPME treatment may be due to adequate supply of bypass protein that increased the availability of amino acids for absorption from the small intestine[24]. Goonewardene *et al.*[25] reported that feeding high-energy and protein concentrate mix to wethers post-weaning resulted in significant improvements in live-weight, efficiency, carcass weight and rib-eye area.

However, the low ADG of ewe and ram lambs on HPHE treatment contradicts the notion that the higher the protein-content in a diet the higher the ADG. The low ADG of lambs on HPHE might have occurred due probably to increase in the deposition of body fat and concomitant decrease in the percentage of lean tissue; or that available proteins in the HPHE and LPME treatments were not properly utilized for maximum growth rate. Generally, protein requirements of sheep in the tropics are higher due to heat-mediated impairment of protein metabolism and increase protein losses in sweating. The inference from this trial therefore was that protein synthesis in the lambs on HPHE and LPME treatments did not match with protein utilization and this resulted in reduced growth rate.

Karim *et al.*[26] reported that sheep still had lower weight gain at higher protein retention due to quality and availability of protein. Live-weight gains of lambs in this trial are however, higher than those reported by Karim *et al.*[26,24] for growing sheep on varying protein and energy diets in India.

Water intake of lambs in the concentrate mixtures was in the following order: MPME >LPME > HPHE > HPLE > HPME. Lambs on MPME treatment that had higher forage intake consumed more water and this observation agrees who reported that water intake is considerably related to forage intake. Also, Giger-Reverdin and Gihad[27] reported that DM and water intakes are highly correlated and WI of sheep is strongly influenced by the water content of the feed. Feed efficiency (kg DMI/kg live-weight gain) followed the trend of ADG. In this study better-feed efficiency was obtained in lambs on HPME, MPME and HPLE treatments.

Lambs on HPHE, HPME and HPLE treatments had higher concentration of blood urea-N (BUN). Available CP contents of the treatments contributed to the high concentration of blood urea-N obtained in lambs. Dietary protein level and intakes were observed to have influence on blood urea-N of lambs used in this trial. High protein intake causes high urea synthesis from large proportion of urea ingested and this could result in high blood urea-N concentration. BUN concentrations in the lambs are within the ovine reference range[28].

Lambs on HPHE treatment had a higher blood glucose concentration. The effect of nutrient intake upon blood glucose level in the ruminant is negligible because of the fermentation that takes place in the rumen. Fisher *et al.*[29] indicated that many factors could influence concentration of blood metabolites in ruminants however blood glucose concentration could be used to predict energy intake and efficiency of utilization. In this trial the efficiency of utilization of protein and available starch in the concentrate mixtures seems to be responsible for the variations obtained in the concentration of blood glucose of lambs in the different treatments. Therefore it could be suggested that there was an inter-relationship of protein and energy intake that influenced the blood glucose concentration of lambs in the different treatments.

Lambs on the HPME treatment were higher in OM and CP digestibility and this may have influenced the ADG and this observation agreed with Premaratu *et al.*[30] that high OM digestibility improved ADG and performances of sheep, respectively. Digestibility of the fibre fractions (NDF, ADF, ADL and hemicellulose) is determined by the rate of passage, retention time and ultimately the utilization of other nutrients by the animal for growth and other physiological functions. The digestibility of the NDF fraction by the lambs in the five treatments was not significantly different from each other therefore; the differences in DMI, ADG and apparent digestibility of other nutrients by lambs cannot be associated with the digestibility of NDF. Increased dietary protein did not depress the digestibility of the fibre fractions and this observation differs from the report of Adeneye and Oyenuga[3].

Among the lambs in the different treatments those on LPME had low DM, OM, CP and ADF digestibilities and subsequently low ADG. CP content is important in the digestibility and utilization of other nutrients and the overall performance of sheep. Variation in digestibility of CP by the lambs was due to the variable levels of coconut meal incorporated in the formulation of the five concentrate mixtures or possibly a reflection of low Daily Crude Protein (DCP) intake. The digestibility of energy in the high and medium energy concentrate mixtures compared to the lower energy concentrate mixture cannot be associated with either lower fibre content or low DMI.

DCP intake of the lambs on the concentrate mixtures was higher than NRC[13] values. Also DEI followed the trend of available energy in the diets. Subsequently, ME concentration of the lambs' diet was lower than NRC[13] value for weaned lambs weighing between 20 to 35 kg. In this trial, treatments and sex had effect on DCP intake and the lambs that had the highest DCP intake showed greater response to DEI and ME, however, these responses were not effectively converted to lean tissue especially for lambs of both sexes on the HPHE and LPME treatments.

CONCLUSION

Based on available data, the best growth performance was recorded in the lambs under HPME and MPME treatment followed by those on HPLE. This observation further supports the early notion that dietary energy and protein should be in equilibrium to obtain reasonable DMI and ADG. Lambs on HPME and MPME treatments consumed 10.8 and 8.7 g CP/kg $^{0.75}$/day had similar ADG of 140 and 111, respectively. This trial proved that sex of lambs and dietary treatments have influence on DMI, nutrient digestibility and consequently growth rate. Available data therefore demonstrated that dietary crude protein and that ranged between 15 to 16.5% CP (daily protein intake of 6.8-7.7 g/kg $^{0.75}$/day); and 17.6 to 19.0 MJ GE/kg BW (10.9-11.8 digestible energy KJ/kg DM), respectively will satisfy the requirements of ewe and ram lambs of the Fiji Fantastic sheep for maximum growth in the tropical environment of Fiji. In conclusion all the treatments with the exception of the LPME concentrate mixture are likely to ensure adequate supply of available nutrients and energy for rumen degradation. However, the HPME treatment that had 16.5% CP (daily protein intake of 6.8 g/kg $^{0.75}$/day) plus 19.0 MJ GE/kg BW (11.7 digestible energy KJ/kg DM) was the best because the lambs on it had better average live weight gain at 121 g/lamb/d.

ACKNOWLEDGEMENT

IR is grateful to Dr. Peter Saville (formerly of SPC, Livestock Section) for funding the laboratory analyses of samples. He is also grateful to staff of the Fiji Agricultural Chemistry Laboratory, Nasouri, Fiji and Chemistry Laboratory, Agricultural Research Institute, Boroko, NCD, Papua New Guinea for chemical analyses of samples and finally to Dr. Kwadwo Ofori, of the Crop Science Department, School of Agriculture, The University of the South Pacific, Apia, Samoa for the statistical analysis of data.

REFERENCES

1. Manueli, P.R., 1997. Sheep in the Humid Tropics-Evolution of the Fiji Sheep. Australian Sheep Veterinary Society Conference Proceedings. University of New England, Armidale, NSW, Australia, pp: 326-330.
2. Adeneye, J.A. and V.A. Oyenuga, 1976. Energy and Protein requirements of the West African Dwarf Sheep. 1. Effects of feeding four levels of dietary energy to sheep. East Afric. Agric. Forest. J., 42: 89-97.
3. Adeneye, J.A. and V.A. Oyenuga, 1976. Energy and Protein requirements of the West African Dwarf Sheep. 2. Increasing the levels of dietary protein to sheep. East Afric. Agric. Forest. J., 42: 98-106.
4. Aregheore, E.M. and R. Tembo, 1997. The utilization of complete rations based on crop residues by the blackhead sheep. Scientia Agric. Boh., 28: 292-300.
5. Adu, I.F. and E.A. Olaloku, 1976. Studies on feed intake in the West African Dwarf sheep. East Afric. Agric. Forest. J., 42: 224-230.
6. Crampton, E.M., 1956. Applied Animal Nutrition. The use of feedstuffs in the formulation of livestock rations. Bailey Brothers and swifen Limited, London, pp: 458.
7. Leng, R.A., 1990. Factors affecting the utilization of poor quality forage by ruminants particularly under tropical conditions. Nutr. Res. Rev., 3: 277-303.
8. Association of Official Analytical Chemist (AOAC), 1995. Official Methods of Analysis, 16th Edn., AOAC, Arlington, VA.
9. Van Soest, P.J., J.B. Roberts and B.A. Lewis, 1991. Methods for dietary fibre, neutral detergent fibre and non- starch polysaccharides in relation to nutrition. J. Dairy Sci., pp: 3583-3597.
10. Fawcett, J.K. and J.E. Scott, 1960. A rapid and precise method for rapid determination of urea. Clin. Path., 13: 156.
11. Kunst, A., B. Draeger and J. Ziegenhorn, 1983. UV-method with hexokinase and glucose 6-phosphate dehydrogenase. Methods of enzymatic analysis (6). Bergmeyer, HU, Ed. Verlag Chemie, Deerfield, pp: 163-172.
12. Minitab for Windows, 2000. Minitab release - version 13, Minitab Incorporation, 3081 Enterprose Drive, State College, Pennsylvania USA., pp: 16801-3008, 814-223-3280.
13. National Research Council (NRC), 1985. Nutrient requirements for sheep 6th revised Edn. National Academy Press, Washington D.C.
14. National Research Council (NRC), 2001. Nutrient requirements of dairy cattle 7th Edn. National Academy Press Washington, D.C.
15. Lu, C.D. and Potchoiba, M.J., 1990. Feed intake and weight gain of growing goats fed diets of various energy and protein levels. J. Anim. Sci., 68: 1751-1759.
16. Van Man, G. and H. Wiktorsson, 2003. Forage yield, nutritive value, feed intake and digestibility of three grass species as affected by harvest frequency. Trop. Gld., 37: 101-110.
17. Meissner, H.H., H.H. Koster, S.H. Nieuwoudt and R.J. Coetzl, 1991. Effect of energy supplementation on intake and digestion of early and mid season rye grass and Panicum/ smuts finger hay and in Sacco disappearance of various forage species. South Afri. J. Anim. Sci., 21: 33-42.
18. Van Soest, P.J., 1965. Symposium on factors influencing the voluntary intake in relation to chemical composition and digestibility. J. Anim. Sci., 24: 834-843.
19. Agricultural Research Council (ARC), 1980. The Nutrient Requirements of Ruminant Livestock. CAB International, Wallingford, Oxon.

20. Andrews, R.P. and E.R. Orskov, 1970. The nutrition of early-weaned lambs. 1. The influence of protein concentrate and feeding levels on rates of gain in body weight. J. Anim. Sci., 75: 11-18.
21. Abouheif, M.A., M.S. Kraides and R.A. Shatat, 1992. Effect of docking and sex of lambs on carcass characteristics of fat-tailed Nadji sheep. J. Applied Anim. Res., 1: 91-101.
22. Aregheore, E.M., 1997. Effect of sex on feed intake, growth and nutrients digestibility in Blackhead sheep fed complete mash rations of crop residues. J. Anim. Feed Sci., 6: 71-79.
23. Aregheore, E.M., T.A. Job and H.S.A. Aluyi, 1988. The maize replacement value of cassava flour in rations for growing ewe lambs. Anim. Feed Sci. Technol., 20: 233-240.
24. Karim, S.A. and A. Santra, 2003. Nutrient requirements for growth of lambs under hot semiarid environment. Asian-Austr. J. Anim. Sci., 16: 665-671.
25. Goonewardene, L.A., E. Okine, N. Pactrick, P.A. Day, H.D. Scheer and A. Suleiman, 2002. Effect of feeding high energy or high-energy protein diets to goats. Can. J. Anim. Sci., 82: 119-121.1.04
26. Karim, S.A., A. Santra and V. Sharama, 2001. Growth performance of weaner lambs maintained on varying levels of dietary protein and energy in the pre- weaning phase. Asian-Austr. J. Anim. Sci., 14: 1394-1399.
27. Giger-Reverdin, S. and E.A. Gihad, 1991. Water metabolism and intake in goats. Goat nutrition, EAAP, publication no. 46, Pudoc, Wageningen.
28. Hallford, D.M. and M.L. Gaylean, 1982. Serum profiles in fine wool sheep. Bovine Prac., 3: 26.
29. Fisher, L.J., P.E. Donnelly, J.B. Hutton and D.M. Duganzich, 1974. Relationship between levels of feeding and certain blood metabolites in dairy cows in mid lactation. J. Agric. Sci., (Camb), 84: 29-37.
30. Premaratne, S., J.V. Bruchem, X.B. Chen, H.G.D. Perera and S.J. Oosting, 1998. Effects of type and level of forage supplementation on voluntary intake, digestion, rumen microbial protein synthesis and growth in sheep fed a basal diet of rice straw and cassava. Asian-Austr. J. Anim. Sci., 11: 692-696.