Research Article

Commercial Concentrate Supplementation in Phan Rang Sheep Diets: Effects on Digestibility Traits, Growth and Carcass Performance

Nguyen Huu Van[1*], Nguyen Thi Mui[1], Dinh Van Dung[1], Van Ngoc Phong[1], Tran Ngoc Long[1], Le Tran Hoan[1], Le Duc Thao[1], Vo Thi Minh Tam[1], Ngo Mau Dung[1], Bui Van Loi[1], Nguyen Xuan Ba[1], Ton Nu Minh Thi[2], Nishino Naoki[2]

[1]*Faculty of Animal Sciences and Veterinary Medicine, University of Agriculture and Forestry, Hue University, Vietnam;* [2]*Graduate School of Environmental and Life Science, Okayama University, Japan.*

Abstract | This study aimed to evaluate the effects of using different levels of commercial concentrate in the diet on nutrient digestibility, rumen volatile fatty acid (VFA) profile, growth and carcass performance of Phan Rang sheep raised in Ninh Thuan province, Vietnam. Twenty-five intact male Phan Rang sheep averaging body weight of 15.4 ± 1.3 (SD) kg/animal were randomly assigned to five groups with different levels of concentrate, including: control (C) (*ad libitum* access to grass feeding); 0.75% (control plus 0.75% of concentrate); 1.5% (control plus 1.5% of concentrate); 2.25% (control plus 2.25% of concentrate) and 3.0% (control plus 3.0% of concentrate) as a percentage of live weight on dry matter basis. Fifteen lambs (three of each treatment) were slaughtered at the end of the experiment (90th day). The results indicated that dry matter intake (%DM/kgLW) and daily gain weight (DGW) of the animals increased linearly as concentrate level increased in the diet. The average DGW of the animals was significantly higher in treatments 3.0% and 2.25% (161.3g/day and 117.1g/day, respectively). Concentrate supplement had significant effects on apparent digestibility of the animals where crude protein (CP) digestibility increased as concentrate level increased, whereas digestibility of neutral detergent fiber (NDF) decreased. There were no significant differences in pH values, ammonia and VFA concentrations in rumen fluid between treatments before and 4h after feeding. The pH values remained in critical rumen pH range of 6.0-7.0 for optimum microbial growth and nutrient utilization. Hence, this study demonstrated that increasing concentrate levels in the diets for Phan Rang sheep up to 2.25% or 3.0% of live weight increased DGW, carcass performance and improved economic benefit for farmers without any adverse effects on nutrient digestibility and rumen fermentation of the animals.

Keywords | Phan Rang sheep, Concentrate, Rumen fermentation, Digestibility, Growth, Carcass

Received | September 26, 2023; **Accepted** | November 02, 2023; **Published** | December 14, 2023
***Correspondence** | Nguyen Huu Van, Faculty of Animal Sciences and Veterinary Medicine, University of Agriculture and Forestry, Hue University, Vietnam; **Email:** nguyenhuuvan@huaf.edu.vn, nhuuvan@hueuni.edu.vn
Citation | Van NH, Mui NT, Dung DV, Phong VN, Long TN, Hoan LT, Thao LD, Tam VTM, Dung NM, Loi BV, Ba NX, Thi TNM, Naoki N (2024). Commercial concentrate supplementation in phan rang sheep diets: Effects on digestibility traits, growth and carcass performance. Adv. Anim. Vet. Sci., 12(1):1-8.
DOI | https://dx.doi.org/10.17582/journal.aavs/2024/12.1.1.8
ISSN (Online) | 2307-8316

INTRODUCTION

Vietnam has a small ruminant animal group called Phan Rang sheep whose tail is short and thin (Chon, 2000). The sheep originally came from Mongolia and China (Nguyen *et al*., 2005) and has been widely raised and adapted well with the hot and dry weather in Ninh Thuan province, which accounts for the highest sheep population (94%) in Vietnam with an estimation of more than 107 thousand heads in 2022 (General Statistic Office, 2022). Hence, Phan Rang sheep has gradually become a local and famous animal of Ninh Thuan farmers.

In Ninh Thuan, sheep flocks are raised mostly under severe environments where the feed shortage is the major constraint to their production development. Sheep are freely raised in crop fields where rice and other cultivars have been harvested and left crop residues. Hence, these feed resources are normally low in nutrition, energy and digestible proteins. Moreover, the continuous and rapid increase of human demand for small ruminant meat, especially lambs and goat meat, while the decreasing tendency of rangelands for grazing brought about an increasing pressure on sheep husbandry systems. Thus, concentrate supplementation is highly needed for stall-fed and free grazing animals to meet their nutrient demands and improve their production performance.

Concentrate supplementation has been widely used on ruminant animals to improve animal performance and production, including goat and sheep fattening (Salim *et al*., 2002; Szumacher-Strabel *et al*., 2002; Tripathi *et al*., 2007; Cantalapiedra-Hijar *et al*., 2009; Majdoub-Mathlouthi *et al*., 2013); however, there is no report on concentrate supplement for Phan Rang sheep in the aspects of itself-animal effects and economy impacts for local farmers. Therefore, this research was conducted to examine the effects of different concentrate levels in the diets on nutrient digestibility; rumen pH, ammonia, and volatile fatty acid profile; growth performance and meat production of the Phan Rang sheep.

MATERIALS AND METHODS

Study site

The experiment was conducted at the Goat and Sheep Breeding Research Station in Ninh Thuan located at 11°45'34.7"N latitude and 109°04'28.3"E longitude. The climate is hot and semi-arid. The study was initiated in July and ended in September, 2022. During the experiment, the average ambient temperature ranged from 29-31°C and relative humidity varied from 50-55%.

Animals and housing

The research was carried out on 25 Phan Rang male sheep weighed 15.4 ± 1.3kg (3-4 months). The sheep was individually housed in pens (1.4×1.8×1.3 m) with separate feeding trough and freely accessed to fresh tap water.

Experimental design and feeding trial

The animals were allowed to have 2-weeks adaption period before starting the experiment. All the animals were weighed again before randomly allocated to five experimental treatments. The experiment was designed as completely randomized design with 5 treatments on 25 Phan Rang intact male sheep and 5 replications (5×5= 25). The five treatments were: control (C) (*ad libitum* access to grass feeding); 0.75% (control plus 0.75% of commercial concentrate); 1.5% (control plus 1.5% of commercial concentrate); 2.25% (control plus 2.25% of commercial concentrate) and 3.0% C (control plus 3.0% of commercial concentrate) as a percentage of live weight on dry matter basis. The animals were fed concentrate for a period of 90 days. The body live weight of the animals was measured every 14 days to calculate gained weight and adjust the concentrate supplementation levels for each animal.

Fresh Guinea grass (*Panicum maximum* Jacq.) was harvested twice daily in the morning and in the afternoon. Animals were fed concentrate 30 minutes before feeding *ad libitum* Guinea grass at 4 times per day (at 7h30; 10h30; 13h30 and 16h30). Chemical composition of the grass and commercial concentrate were shown at Table 1. Feed intake of the animals was daily recorded by measuring individual daily feeding supply and refusal. It was then calculated for average feeding intake by dry matter. Deworming was applied at the beginning of the experiment using "Albendazole" at 3ml/head of sheep.

Table 1: Chemical composition of the grass and commercial concentrate.

Chemical composition	Guinea grass	Commercial concentrate
Dry matter (% as fresh matter)	29.12	88.15
Organic matter (% DM)	92.76	90.34
Crude protein (% DM)	4.29	19.37
Neutral detergent fiber (% DM)	73.12	35.54
Ether extract (% DM)	1.70	2.67

DM: Dry matter

Digestibility trial

Digestibility trial was conducted for a week since 45th day of the experiment period. Feed sub-samples, feed refusals and feces were collected daily and analyzed to calculate nutrition digestibility.

Rumen fluid sample collection and pH measurement

On the last day of the digestibility trial, rumen fluid of each sheep was taken using esophageal-rumen tube at 0 and 4 hours after feeding concentrate. The rumen fluid was then filtered through a muslin cloth to remove coarse particles. Thereafter, pH values were directly measured by pH machine (HANNA HI8314, Romania). The rumen fluid tubes were then stored at -20°C for further analysis of ammonia concentration and volatile fatty acids.

Carcass performance lamb and meat quality

At the end of the experiment, 03 lambs with body weight closed to mean weight of their treatment were selected for carcass assessment. Carcass was weighed immediately to obtain hot carcass weight. Longissimus lumborum muscle was taken to evaluate chemical compositions of lamb meat.

Sample analysis

Nitrogen concentration of feeds and animal feces was determined by using the Kjeltec 8200 following the Kjeldahl method (AOAC, 1990). Neutral Detergent Fiber was analysed following the protocol of Vogel *et al.* (1999) using the Ankom 2000 Fiber Analyser (Ankom®, Tech. Co., Fairport, NY, USA). Ether extract was determined using the Soxtec 2050 (Foss, Sweden) (AOAC, 1990). Ammonia concentration and volatile fatty acids (VFAs) in the rumen fluid were analysed at the laboratory of Animal Nutrition, Okayama University, Japan using the standard Gas Chromatography Method.

Statistical analysis

Experimental data were analysed using General Linear Model by SPSS version 20.0. The analysis fitted model was:

$$Y_{ij} = \mu + C_i + \varepsilon_{ij}$$

Where; μ = The overall mean; C_i = The fixed effect of treatment (concentrate levels); i= Control; 0.75, 1.5, 2.25, 3.0; ε_{ij} = The random error; Tukey's statistic was used to test differences ($p<0.05$) among means.

RESULTS

Feed intake

Concentrate level in the diet had significant effects ($p<0.05$) on average feed intake of sheep, where grass feed intake decreased with an increase of concentrate level (Table 2). Grass feed intake of animals in control and treatment 0.75% was significantly ($p<0.05$) higher than those in treatments 1.5%, 2.25% and 3%. As a result, there was a significant effect ($p<0.05$) in total dry matter intake of animals among different treatments (Table 2).

Nutrient digestibility

Concentrate supplemented in the diet had significant ($p<0.05$) effects on nutrient digestibility of DM, OM, CP and NDF (Table 3). However, the differences did not show clearly among treatments. The highest OM digestibility was recorded in treatment 0.75% (77.1%), which was significantly different from those in treatment 2.25% (71.2%). The greatest CP digestibility was in treatment 3.0% (65.9%) which was significantly higher than in control and treatment 0.75% (52.2% and 59.0%, respectively). In contrast, the digestibility of NDF in the control (65.4%), treatments 0.75% (65.1%) and 1.5% (59.3%) was significantly ($p<0.001$) higher than in treatments 2.25% (54.3%) and 3.0% (53.6%) (Table 3).

Table 2: Effects of concentrate supplementation on feed intake of animals (Means ± SD)

Parameters	Treatments					p
	Control	0.75%	1.5%	2.25%	3.0%	
Feed intake (gDM/animal/day)						
Grass	641.1 ± 29.4^{a}	611.7 ± 11.9^{a}	470.5 ± 38.7^{b}	481.4 ± 21.2^{b}	473.6 ± 19.2^{b}	0.001
Concentrate	-	135.1 ± 6.7^{a}	251.7 ± 47.4^{b}	429.0 ± 31.9^{c}	636.2 ± 43.7^{d}	0.001
Total	641.1 ± 29.4^{a}	746.7 ± 11.3^{b}	722.2 ± 85.4^{ab}	910.4 ± 44.3^{c}	1109.8 ± 61.2^{c}	0.001
Feed intake (% as DM/100kgLW)						
Grass	4.1 ± 0.1^{a}	3.4 ± 0.2^{b}	2.7 ± 0.2^{c}	2.5 ± 0.2^{cd}	2.2 ± 0.1^{d}	0.001
Concentrate	-	0.7 ± 0.0^{a}	1.5 ± 0.1^{b}	2.2 ± 0.1^{c}	2.9 ± 0.1^{d}	0.001
Total	4.1 ± 0.1^{a}	4.1 ± 0.2^{a}	4.2 ± 0.2^{a}	4.7 ± 0.2^{b}	5.1 ± 0.1^{c}	0.001

^{abc} Means within the same row sharing the same letter are not significantly different; SD: Standard deviation; p: probability; DM: Dry matter; LW: Live weight

Table 3: Effects of concentrate supplementation on digestibility of the animals (Means ± SD).

Digestibility	Treatments					p
	Control	0.75%	1.5%	2.25%	3.0%	
DM (%)	64.6 ± 0.7^{ab}	66.1 ± 3.0^{a}	62.4 ± 4.8^{ab}	60.4 ± 1.9^{b}	61.9 ± 1.1^{ab}	0.029
OM (%)	72.5 ± 1.3^{ab}	77.1 ± 3.8^{a}	72.7 ± 3.3^{ab}	71.2 ± 1.9^{b}	76.1 ± 3.4^{ab}	0.020
CP (%)	52.2 ± 1.1^{a}	59.0 ± 2.9^{b}	62.1 ± 4.3^{bc}	62.6 ± 2.1^{bc}	65.9 ± 1.1^{c}	0.001
NDF (%)	65.4 ± 0.76^{a}	65.1 ± 3.7^{a}	59.3 ± 5.9^{ab}	54.3 ± 2.8^{b}	53.6 ± 2.4^{b}	0.001

^{abc} Means within the same row sharing the same letter are not significantly different; SD: Standard deviation; p: probability; DM: Dry matter; OM: Organic matter; CP: Crude protein; NDF: Neutral detergent fiber

Links Researchers

Table 4: Effects of concentrate supplementation on live weight and daily gain weight of the animals (Means±SD).

Day	Treatments					p
	Control	0.75%	1.5%	2.25%	3.0%	
Live weight (kg/animal)						
1	14.7 ± 0.4	15.4 ± 1.1	15.2 ± 1.8	15.4 ± 1.7	15.5 ± 0.9	0.930
15	15.7 ± 0.4	16.6 ± 0.9	15.6 ± 2.3	16.6 ± 1.8	17.6 ± 1.8	0.300
30	15.4 ± 0.4^{a}	16.6 ± 0.9^{ab}	15.6 ± 3.5^{ab}	17.6 ± 1.5^{ab}	20.0 ± 1.4^{b}	0.007
45	15.8 ± 0.4^{a}	18.8 ± 0.8^{ab}	17.4 ± 3.6^{ab}	20.2 ± 1.8^{bc}	23.8 ± 1.5^{c}	0.001
60	16.3 ± 0.8^{a}	20.2 ± 1.1^{b}	19.6 ± 3.3^{ab}	22.4 ± 1.5^{b}	26.2 ± 1.1^{c}	0.001
75	16.6 ± 1.0^{a}	20.2 ± 1.1^{b}	20.4 ± 2.9^{b}	24.0 ± 1.2^{c}	28.4 ± 1.1^{d}	0.001
90	16.9 ± 1.2^{a}	21.4 ± 1.1^{b}	22.8 ± 3.2^{bc}	26.0 ± 1.5^{c}	30.0 ± 1.5^{d}	0.001
Daily gain weight (g/day)						
Average	25.6 ± 9.1^{a}	65.3 ± 9.1^{b}	85.3 ± 25.6^{b}	117.1 ± 8.5^{c}	161.3 ± 8.5^{d}	0.001

[abc] Means within the same row sharing the same letter are not significantly different; SD: Standard deviation; p: probability

Table 5: pH value and ammonia concentration of rumen fluid before and after 4 hours feeding (Means ± SD).

Parameters	Treatments					p
	Control	0.75%	1.5%	2.25%	3.0%	
pH values						
Before feeding	6.45 ± 0.03^{ab}	6.43^{a} ± 0.08	6.46 ± 0.04^{ab}	6.57 ± 0.10^{b}	6.45 ± 0.04^{ab}	0.029
After feeding	6.43 ± 0.03	6.34 ± 0.11	6.39 ± 0.14	6.31 ± 0.13	6.26 ± 0.09	0.148
Ammonia values (mg/L)						
Before feeding	70.4 ± 1.0	70.1 ± 17.7	90.2 ± 11.1	82.8 ± 28.8	84.1 ± 6.7	0.235
After feeding	69.5 ± 9.7	63.9 ± 16.3	65.0 ± 6.1	68.1 ± 19.3	67.9 ± 10.6	0.961

[abc] Means within the same row sharing the same letter are not significantly different; SD: Standard deviation; p: probability.

Animal live weight and daily gain weight

Concentrate supplement did not have significant effects on live weight (LW) of the animals between treatments on the first 15-days of the experiment, whereas the significant effects were obviously observed from day 30 onwards (Table 4). At the end of the experiment, LW of the animals in the control was significantly ($p<0.001$) lower than in the concentrate-supplemented groups. The highest LW of the animals was recorded in treatment 3.0% (30kg/head) which was significantly ($p<0.001$) higher than others treatment groups.

Daily gain weight (DGW) of the animals was significantly ($p<0.001$) affected by levels of concentrate (Table 4). Average DGW significantly increased when the proportion of concentrates in the diets increased. The highest DGW was significantly recorded in treatment 3.0% (161.3g/day), followed by treatment 2.25% (117.1g/day) and the lowest DGW was observed in control (25.6g/day). There was no significant difference in DGW of the animals between treatments 0.75% and 1.5% (Table 4).

pH value and ammonia profile

pH values were significantly ($p<0.05$) different among treatments before feeding, especially there was a statistically significant difference in pH values between treatment 0.75% (6.43) and treatment 2.25% (6.57). However, these values did not show significant differences after 4h feeding (Table 5). In general, concentrate supplement caused a reduction in ammonia values, but there were no significant differences in ammonia values between treatments before ($p=0.235$) and after ($p=0.961$) feeding (Table 5).

VFA profile on rumen fluid before (0h) and after 4h (4h) feeding

Concentrate supplement did not cause significant differences in the concentration of acetate, propionate, butyrate and sum of VFA among treatments before and after feeding. However, the sum of VFA concentration tended to be increased after feeding. In general, the major proportion of VFA profile in rumen fluid was acetate, then followed by propionate and the lowest percentage was butyrate (Table 6).

Carcass performance and chemical composition of meat

Concentrate supplement had significant effects on percentage of carcass performance between 5 treatments. The highest carcass percentage was recorded in treatment 3.0% (51.8%) which was significantly ($p<0.001$) higher than treatments 1.5% (46.0%), 0.75% (44.7%), and control (43.9%). Concentrate supplement had significant effects on chemical composition of lamb meat. Dry matter, crude protein and intramuscular fate (%) increased linearly with increasing supplement level; and it was significantly ($p<0.01$) lower in control compared to supplemented treatments (Table 7).

Table 6: Volatile fatty acid (VFA) of rumen fluid before and 4h after feeding (Means ± SD).

Parameters	Treatments					p
	Control	0.75%	1.5%	2.25%	3.0%	
Acetate concentration (mmol/L)						
Before feeding	33.2 ± 4.1	46.1 ± 11.7	42.2 ± 5.1	34.2 ± 9.1	36.1 ± 9.8	0.114
After feeding	47.9 ± 3.6	57.0 ± 10.9	47.0 ± 11.1	42.3 ± 27.7	46.8 ± 8.3	0.630
Propionate concentration (mmol/L)						
Before feeding	5.6 ± 1.0	7.9 ± 2.6	8.8 ± 1.5	8.0 ± 2.5	8.7 ± 1.9	0.126
After feeding	9.4 ± 0.9	10.8 ± 2.3	9.4 ± 6.4	8.6 ± 3.6	12.2 ± 3.6	0.552
Iso-Butyrate concentration (mmol/L)						
Before feeding	0.5 ± 0.1	0.5 ± 0.2	0.5 ± 0.1	0.4 ± 0.1	0.6 ± 0.1	0.167
After feeding	0.6 ± 0.1	0.4 ± 0.1	0.3 ± 0.1	0.6 ± 1.0	0.3 ± 0.1	0.651
n-Butyrate concentration (mmol/L)						
Before feeding	4.0 ± 0.7	4.8 ± 1.9	5.8 ± 0.7	4.6 ± 1.1	5.4 ± 1.3	0.178
After feeding	5.9 ± 0.5	6.3 ± 1.3	5.6 ± 1.2	3.9 ± 2.6	5.6 ± 1.3	0.197
Sum of VFA (mmol/L)						
Before feeding	43.4 ± 5.7	59.3 ± 15.9	57.3 ± 6.6	47.2 ± 12.4	50.8 ± 12.7	0.184
After feeding	63.8 ± 4.2	74.5 ± 14.2	62.3 ± 14.6	55.6 ± 35.5	64.9 ± 12.2	0.645

^{abc} Means within the same row sharing the same letter are not significantly different; SD: Standard deviation; p: probability

Table 7: Carcass performance and chemical composition of lamb meat (Means ± SD).

Parameters	Treatments					p
	Control	0.75%	1.5%	2.25%	3.0%	
Carcass performance						
Slaughter weight (kg)	17.0 ± 1.7^{a}	21.3 ± 0.6^{b}	23.0 ± 1.0^{bc}	26.0 ± 1.0^{c}	30.3 ± 1.5^{d}	0.001
Carcass weight (kg)	7.3 ± 1.2^{a}	9.7 ± 0.6^{ab}	10.7 ± 1.2^{bc}	12.7 ± 1.2^{c}	15.6 ± 1.2^{d}	0.001
Dressing percentage (%)	43.9 ± 2.9^{a}	44.7 ± 1.1^{a}	46.0 ± 1.9^{a}	48.3 ± 2.1^{ab}	51.8 ± 1.7^{b}	0.005
Chemical composition of lamb meat (% as fresh matter)						
Dry matter	18.1 ± 1.7^{a}	20.7 ± 0.4^{ab}	21.1 ± 0.8^{ab}	22.4 ± 0.5^{b}	23.2 ± 1.5^{b}	0.002
Crude protein	16.3 ± 1.2^{a}	18.4 ± 0.09^{b}	18.6 ± 0.4^{b}	19.3 ± 0.5^{b}	20.0 ± 0.9^{b}	0.001
Intramuscular fat	0.96 ± 0.04^{a}	1.04 ± 0.02^{ab}	1.04 ± 0.03^{ab}	1.1 ± 0.04^{b}	1.1 ± 0.04^{b}	0.002
Ash	0.9 ± 0.6	1.3 ± 0.3	1.5 ± 0.4	2.0 ± 0.1	2.1 ± 0.6	0.052

^{abc} Means within the same row sharing the same letter are not significantly different; SD: Standard deviation; p: probability

Table 8: Economic efficiency calculation of different treatments.

No.	Parameters	Treatments				
		Control	0.75%	1.5%	2.25%	3.0%
1	Concentrate consumption (kg/animal/day)	0	0.135	0.251	0.429	0.636
2	Concentrate price (vnd/kg)	11,000	11,000	11,000	11,000	11,000
3	Animal gain weight (g/day)	25.6	65.3	85.3	117.1	161.3
4	Animal price (vnd/kg)	110,000	110,000	110,000	110,000	110,000
5=1*2	Sum of investment (vnd/day)	0	1,485	2,761	4,719	6,996
6=3*4	Sum of income (vnd/day)	2,816	7,183	9,383	12,881	17,722
7=(6-5)*90	Benefit (vnd/90 days)	253,440	512,820	595,980	734,580	967,230

vnd: Vietnamese Dong (Vietnamese currency)

Economic efficiency

Concentrate supplement had greatly increased benefits for farmers. The higher concentrate levels applied; the more benefit farmers gained. The highest benefit value was observed in treatment 3.0%, with 967,230 vnd/head compared to the lowest concentrate level treatment (512,820 vnd/head) and control (253,440 vnd/head) for a period of 90-day fattening (Table 8).

DISCUSSION

Feed intake and body gained weight

It is necessary to quantify dry matter intake (DMI) for an estimation of nutrient consumption by ruminants. Animals consume less roughage when concentrate diet increases (Tripathi *et al*., 2007; Papi *et al*., 2011; Quan *et al*., 2014). In this study, grass DMI was reduced when the level of concentrate diet increased. Experimental animals consumed 4.1% of grass DM without concentrate supplement. This value decreased to 3.4% and 2.2% when the animals were supplied with 0.75% and 3% of concentrate, respectively. The finding in this research is consistent with some other researchers (Holden *et al*., 1995; Reeves *et al*., 1996; Tripathi *et al*., 2007; Papi *et al*., 2011; Quan *et al*., 2014) who revealed that forage intake reduces with the increased intake of supplemental feed due to substitution of grain for forage. With the increase of concentrate level, total DM feed intake (including grass and concentrate) of animals in this study ranged from 4.1% to 5.1%. The quantity feed required for animals depends on size of the animal and their production stage (National Research Council, 2007). In this study, sheep are on the fast-growing stage, so perhaps they need higher energy diet to meet their growing demand. Earlier study conducted by Tripathi *et al.* (2007) also reported that DMI of sheep fed by 1.5% and 2.5% concentrate levels in the diets was 4.2% and 4.9%LW, respectively.

In this study, live body weight and average daily gain weight (DGW) of the animals significantly improved with the increase of concentrate levels. The highest DGW was recorded in treatment 3% with an average of 161g/day, followed by treatment 2.25% with 117g/day, treatment 1.5% was 85.3g/day and DGW of animal without concentrate added was only 25.6 g/day. These results are higher than those reported by Tripathi *et al.* (2007) who revealed that daily gain weight of sheep fed by *ad libitum* and 1.5%BW concentration were 150.7g/day and 77.2 g/day, respectively.

Nutrient digestibility

In this study, though apparent digestibility of DM, OM, CP and NDF was statistically significant effect between treatments, it did not obviously show significant difference between control and treatments, with the exceptions of CP and NDF. CP digestibility in this study increased when the proportion of concentrate in the diet increased, which is in agreement with findings by Haddad (2005) and Cantalapiedra-Hijar *et al.* (2009). High digestibility of CP in treatments 2.25% and 3% is probably due to high amount of CP intake through concentrate provided. In contrast, animals in treatments fed low concentrate level and in control consumed high NDF due to higher fiber intake through roughage source. The animals fed by higher concentrate levels (2.25% and 3%LW) had lower ruminal pH (6.31 and 6.26) than those given concentrate at 0.75% and 1.5%LW after 4h feeding, but the pH values remained in critical rumen pH range of 6.0-7.0 for optimum microbial growth and nutrient utilization (Erfle *et al*., 1982). Though high concentrate supplement induced the decline of pH value in rumen, it did not cause problem of acidosis. The rumen pH higher than 5.9 is considered as normal, while the pH values 5.6 to 5.8 induce a problem of ruminal acidosis (Olson, 1997). The greatest balance of fiber and starch digestion occurs at a rumen pH of around 6.0, with fiber-digesting bacteria surviving best at pH 6.0 to 6.8 and starch-digesting bacteria at pH 5.5 to 6.0. The decline of pH in ruminal fluid fed by high concentrate or grain diets has also been indicated by earlier research (Hristov *et al*., 2001; Tripathi *et al*., 2004, 2007).

Ammonia values in the treatments provided high concentrate levels were higher than control and treatment supplied 0.75% level of concentrate at both points of sample measurement. This could be explained that animals consumed a high amount of CP, which may lead to a faster rate of passage through animal rumen and a higher turn-over of ammonia. However, there was no significant difference in rumen ammonia concentration between treatments after 4 hours feeding.

VFA profile

Volatile fatty acid (VFA) ratios on rumen production are influenced by different factors, including composition of feed (Bergman, 1990; Dijkstra, 1994; Szumacher-Strabel *et al*., 2002). In this study, the results showed that increased concentrate level in the diet resulted in a decrease of acetate proportion while propionate increased. Similar findings have been reported in goat fed by high concentration level (Quan *et al*., 2014) and in cow fed by grass silage (Van Gastelen *et al*., 2015). Changing of VFA profile in rumen fluid has also been reported by some previous research using different types of feeding ingredients in the diet. Adding fish oil in the diet reduced level of acetic acid while it induced an increase of butyric acids (Chamberlain *et al*., 1983; Szumacher-Strabel *et al*., 2002); or increasing corn silage percentage in the diet led to an increase of butyrate proportion in rumen of cows (Van Gastelen *et al*., 2015). In general, concentrate supplement generally did not negatively affect VFA rumen profile of the animals in this study.

Carcass performance

Concentrate supplement had significant effect on carcass performance of the animals. Hot carcass weight and dressing percentage increased when increasing level of concentrate in the diets. Those values were significantly higher in the treatments fed by 2.25% (12.7kg; 48.3%, respectively) and 3.0% (15.6kg; 51.8%, respectively). Carcass performance of sheep in this study was similar to other researchers (Archimède *et al*., 2008; Jacques *et al*., 2011; Papi *et al*., 2011; Majdoub-Mathlouthi *et al*., 2013) who studied the effects of varying concentrate levels in the diets on slaughtering traits of lambs and concluded that carcass performance of lambs increased with increasing level of concentrate.

CONCLUSION AND RECOMMENDATION

Increasing level of concentrate supplement in the diets of Phan Rang sheep up to 2.25% or 3.0% of live weight increased daily gain weight, carcass performance and improved economical benifit for farmers without any adverse effects on nutrient digestibility and rumen fermentation of the animals. Those concentrate levels may be recommended for fattening the lambs by Ninh Thuan local farmers.

ACKNOWLEDGEMENTS

The authors would like to thank all members of Goat and Sheep Breeding Research Centre in Ninh Thuan for kindly supporting us the facility to conduct this experiment. We are also grateful to our students: Mr. Le Minh Can, Mr. Tran Van Hoai Phuoc and Mr. Vo Viet Trieu for their immense technical assistance in taking care of the animals and collecting data during experimental period. This work was supported by the Ministry of Education and Training under the project CT-2021-01-DHH-03.

NOVELTY STATEMENT

This study is the first to evaluate levels of commercial concentrate supplementation for Phan Rang sheep in the aspects of itself-animal effects and economy impacts.

AUTHOR'S CONTRIBUTION

Idea and research design: NHV, DVD, NXB, NTM; Sample collection: NTM, VNP, TNL, LTH, LDT, NMD, BVL; Methodology, chemical analysis and data curation: NHV, NTM, VNMT, TNMT, NN; Statistical analysis: NTM; Writing the original draft and revising the final version: NHV, NTM; Review and editing: All authors. All authors read and approved the final manuscript.

Conflict of interest

The authors have declared no conflict of interest.

REFERENCES

AOAC (1990). Official methods for analysis 15th Edn., Association of Official Analytical Chemists, Washington, DC, USA. pp. 684.

Archimède H, Pellonde P, Despois P, Etienne T, Alexandre G (2008). Growth performances and carcass traits of Ovin Martinik lambs fed various ratios of tropical forage to concentrate under intensive conditions. Small Rumin. Res. 75: 162-170. https://doi.org/10.1016/j.smallrumres.2007.10.001

Bergman E (1990). Energy contributions of volatile fatty acids from the gastrointestinal tract in various species. Physiol. Rev. 70: 567-590. https://doi.org/10.1152/physrev.1990.70.2.567

Cantalapiedra-Hijar G, Yáñez-Ruiz D, Martín-García A, Molina-Alcaide E (2009). Effects of forage: Concentrate ratio and forage type on apparent digestibility, ruminal fermentation, and microbial growth in goats. J. Anim. Sci., 87: 622-631. https://doi.org/10.2527/jas.2008-1142

Chamberlain D, Thomas P, Anderson FJ (1983). Volatile fatty acid proportions and lactic acid metabolism in the rumen in sheep and cattle receiving silage diets. J. Agric. Sci., 101: 47-58. https://doi.org/10.1017/S0021859600036352

Chon TT (2000). Phan Rang sheep-a genetic resource in Vietnam. J. Agric. Sci. Technol.,

Dijkstra J (1994). Production and absorption of volatile fatty acids in the rumen. Livest. Prod. Sci., 39: 61-69. https://doi.org/10.1016/0301-6226(94)90154-6

Erfle J, Boila R, Teather R, Mahadevan S, Sauer F (1982). Effect of pH on fermentation characteristics and protein degradation by rumen microorganisms *in vitro*. J. Dairy Sci., 65: 1457-1464. https://doi.org/10.3168/jds.S0022-0302(82)82368-0

General Statistic Office (2022). Livestock population 2022. Vol. 2023.

Haddad S (2005). Effect of dietary forage: Concentrate ratio on growth performance and carcass characteristics of growing Baladi kids. Small Rumin. Res., 57: 43-49. https://doi.org/10.1016/j.smallrumres.2004.05.001

Holden L, Muller L, Lykos T, Cassidy T (1995). Effect of corn silage supplementation on intake and milk production in cows grazing grass pasture. J. Dairy Sci., 78: 154-160. https://doi.org/10.3168/jds.S0022-0302(95)76625-5

Hristov A, Ivan M, Rode L, McAllister T (2001). Fermentation characteristics and ruminal ciliate protozoal populations in cattle fed medium-or high-concentrate barley-based diets. J. Anim. Sci., 79: 515-524. https://doi.org/10.2527/2001.792515x

Jacques J, Berthiaume R, Cinq-Mars D (2011). Growth performance and carcass characteristics of Dorset lambs fed different concentrates: Forage ratios or fresh grass. Small Rumin. Res., 95: 113-119. https://doi.org/10.1016/j.smallrumres.2010.10.002

Majdoub-Mathlouthi L, Saïd B, Say A, Kraiem K (2013). Effect of concentrate level and slaughter body weight on growth performances, carcass traits and meat quality of Barbarine lambs fed oat hay based diet. Meat Sci., 93: 557-563. https://doi.org/10.1016/j.meatsci.2012.10.012

National Research Council (2007). Nutrient requirements of small ruminants: Sheep, goats, cervids, and new world camelids, 中国法制出版社.

Nguyen TM, Van Binh D, Ørskov E (2005). Effect of foliages containing condensed tannins and on gastrointestinal parasites. Anim. Feed Sci. Technol., 121: 77-87. https://doi.org/10.1016/j.anifeedsci.2005.02.013

Olson JD (1997). The relationship between nutrition and management to lameness in dairy cattle. The Bovine Practitioner, pp. 65-68. https://doi.org/10.21423/bovine-vol1997no31.2p65-68

Papi N, Mostafa-Tehrani A, Amanlou H, Memarian M (2011). Effects of dietary forage-to-concentrate ratios on performance and carcass characteristics of growing fat-tailed lambs. Anim. Feed Sci. Technol., 163: 93-98. https://doi.org/10.1016/j.anifeedsci.2010.10.010

Quan N, Lane P, Van N, Parsons D, Ba N, Malau-Aduli A (2014). Productive performance, rumen volatile fatty acid profile and plasma metabolites of concentrate-supplemented Bach Thao goats in Vietnam. J. Anim. Vet. Adv., 13: 1173-1178.

Reeves M, Fulkerson W, Kellaway R, Dove H (1996). A comparison of three techniques to determine the herbage intake of dairy cows grazing kikuyu (*Pennisetum clandestinum*) pasture. Aust. J. Exp. Agric. 36: 23-30. https://doi.org/10.1071/EA9960023

Salim H, Shahjalal M, Tareque A, Kabir F (2002). Effects of concentrate supplementation on growth and reproductive performance of female sheep and goats under grazing condition. Pak. J. Nutr., 1: 191-193. https://doi.org/10.3923/pjn.2002.191.193

Szumacher-Strabel M, Potkanski A, Kowalczyk J, Cieslak A, Czauderna M, Gubala A, Jedroszkowiak P (2002). Influence of supplemental fat on rumen volatile fatty acid profile, ammonia and pH level in sheep feed standard diet. J. Anim. Feed Sci., 11: 577-588. https://doi.org/10.22358/jafs/67912/2002

Tripathi M, Chaturvedi O, Karim S, Singh V, Sisodiya S (2007). Effect of different levels of concentrate allowances on rumen fluid pH, nutrient digestion, nitrogen retention and growth performance of weaner lambs. Small Rumin. Res., 72: 178-186. https://doi.org/10.1016/j.smallrumres.2006.10.008

Tripathi M, Santra A, Chaturvedi O, Karim S (2004). Effect of sodium bicarbonate supplementation on ruminal fluid pH, feed intake, nutrient utilization and growth of lambs fed high concentrate diets. Anim. Feed Sci. Technol., 111: 27-39. https://doi.org/10.1016/j.anifeedsci.2003.07.004

Van Gastelen S, Antunes-Fernandes E, Hettinga K, Klop G, Alferink S, Hendriks W, Dijkstra J (2015). Enteric methane production, rumen volatile fatty acid concentrations, and milk fatty acid composition in lactating Holstein-Friesian cows fed grass silage-or corn silage-based diets. J. Dairy Sci., 98: 1915-1927. https://doi.org/10.3168/jds.2014-8552

Vogel KP, Pedersen JF, Masterson SD, Toy JJ (1999). Evaluation of a filter bag system for NDF, ADF, and IVDMD forage analysis. Crop Sci., 39: 276-279. https://doi.org/10.2135/cropsci1999.0011183X003900010042x