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Research Article

## Supplementation of crossbred boer goats with cottonseed meal and/or urea enhances estimated metabolizable protein intake, crude protein digestibility and nitrogen retention

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### Abstract

This study aimed to determine feed intake, apparent digestibility, and nitrogen retention of crossbred Boer bucks supplemented with urea or cottonseed meal (CSM) when fed tropical Rhodes (*Chloris gayana*) grass hay (RGH) as a basal diet. Twelve eight-month-old bucks (23.9±1.1 kg live weight) were allocated to one of the four dietary treatments in a randomised block design. The treatments were 1) maize supplement (Control); or maize plus 2) urea supplement (M+U), 3) urea and CSM (M+UCSM); and (4) CSM (M+CSM). All bucks were held in individual metabolism crates for 21 days (11 days of adaptation and 10 days collection period) with ad libitum access to RGH and fresh drinking water in addition to the supplements. A one-way ANOVA and Duncan's multiple range tests were used to test for differences between means at a significance level of  $P < 0.05$ . Results indicated higher feed intake, apparent digestibility of crude protein and digestible nutrient intake in goats supplemented with M+CSM and M+UCSM, but not M+U alone. Supplementation with M+CSM increased nitrogen retention by 300%. Supplementation with M+UCSM and M+CSM increased the total feed intake of Boer goats on tropical grass hay by 13 and 20%, respectively. Supplementation with M+U, M+UCSM, and M+CSM improved the apparent digestibility of crude protein by 9.7, 15.7 and 15.1%, respectively. It can be concluded that total feed intake and nutrient digestibility was increased on growing Boer goats fed RGH as a basal diet supplemented with true protein from CSM or a mixture of true protein and rumen degradable protein from urea.

**Keywords:** Goats, Tropical Forages, Supplementation, Protein, Digestibility.

### Introduction

In the dry season, tropical pastures increase in neutral detergent fibre (NDF) content, vascular tissues become lignified suggest nutrient digestibility, and metabolizable energy (ME) and metabolizable protein (MP) contents are reduced (Evitayani et al., 2005). As a result, meat goats fed these pastures may have insufficient ME and MP to support optimal live weight gain (LWG) necessary for attaining saleable live weights of 35 kg or 75 to 100 g LWG/day over 12 months. Achieving these rates of LWG requires an increase in ME and MP intake to meet requirements for increased

growth. One method to meet the ME and MP requirements of goats is to offer dietary protein supplements in addition to roughages, with the aim of increasing organic matter (OM) digestibility and protein digestibility as indicators of ME (Commonwealth Scientific and Industrial Research Organisations [CSIRO], 2007, pp. 1-70) and MP (National Research Council [NRC], 2007, pp. 81-105) content respectively.

Supplementation of goats fed grass basal diets with different protein sources has generated variable results. For example, Solomon, Melaku and Tolera (2008) utilised 200, 300 or 400 g of cottonseed meal (CSM) to enhance CP intake in grass hay-

fed Sidama goats and reported linear increases in OM and CP digestibility coefficients from 650 to 750 g/kg DM and 410 to 730 g/kg DM, respectively. These increases aligned well with the intakes of CP, rumen-degradable protein (RDP) and undegraded dietary protein (UDP). Similarly, Lallo (1996) linearly increased apparent digestibility of nitrogen in goats from 262 to 742 g/kg DM and nitrogen retention from 0.49 to 5.74 g/d using urea and soybean meal supplementation. The mixture of urea and soybean meal to increase dietary CP to 127 g/kg DM enhanced microbial crude protein yield and absorption in the abomasum and small intestines, thereby increasing nitrogen digestibility and retention in line with Satter and Slyter (1974), who reported that optimal production of ammonia and volatile fatty acids was at 120 g CP/kg DM diet. However, the study of Lallo (1996), showed that the highest OM digestibility (670 g/kg DM) was at 108 instead of 127 g CP/kg DM. From these studies, it is apparent that an increase in OM digestibility coupled with ratio of RDP and UDP may be important for optimising growing kid's performance. The work of Satter and Slyter (1974) suggests that there is a dietary RDP content threshold for optimising the production of microbial protein to increase digestibility. The highest digestibilities were recorded at an RDP to fermentable organic matter ratio of 0.14 (Solomon et al. 2008) and 0.25 (Lallo 1996). This showed that although both ammonia N and amino acids were required to promote the digestion of fermentable OM, there was a higher requirement of urea RDP than cottonseed meal RDP needed to increase microbial crude protein flow from the rumen and total metabolizable protein available from the diet. The amount of RDP in the diet must match available fermentable organic matter (OMF) consumed to optimise microbial crude protein yield (Agricultural Food and Research Council [AFRC], 1993, pp. 15-17; CSIRO, 2007, pp. 83-84). Patterson, Lambert, Muir and Foote (2009) fed one group of goats with sorghum-Sudan hay (CP 69 g/kg DM) only and supplemented three other groups with urea, dextrose or urea plus dextrose, with CP concentrations for the four diets being 69, 88, 68 and 97 g/kg DM, respectively. The study found that OM digestibility was the same for all treatment groups, however, nitrogen retention in the urea plus dextrose supplement was 4.8 g/d, almost twice as high of that in grass hay only (2.3 g/d) and hay plus urea (2.5 g/d) (Patterson et al., 2009). The nitrogen retention values implied that RDP gave better results when mixed with fermentable carbohydrates. In comparison, Lallo (1996) reported that OM digestibility increased as the CP concentration increased from 51 to 108 g/kg DM diet, while Patterson et al. (2009) found that when CP concentration varied between 69 and 97 g/kg DM, OM digestibility was not influenced. This indicated that urea, as an RDP source, produced better outcomes when mixed with a UDP source such as cottonseed meal.

In our current study, we hypothesised that cottonseed meal, as a source of slow-release RDP that matches the needs of rumen microorganisms for ammonia, will increase both OM and CP digestibility when fed to Boer goats on a basal diet of tropical Rhodes grass hay plus maize. In contrast, urea will decrease digestibility due to its rapid ammonia release and dissipation, and will not match the daily requirements of rumen microorganisms for ammonia. We hypothesised further, that a mixture of urea and cottonseed meal will result in a

digestibility value between that of cottonseed meal and urea in goats. Therefore, the main objective of this study was to compare feed intake, apparent digestibility, and nitrogen retention in crossbred Boer kids fed a basal diet of tropical Rhodes grass and supplemented with diverse dietary protein sources of RDP and UDP.

## Materials and methods

### Animal ethics

The use of animals and experimental procedures in this study were approved by the James Cook University Animal Ethics Committee (Permit Number A2130). All experiments were performed by relevant guidelines and regulations of the 2013 Australian Code of Practice for the Care and Use of Animals for Scientific Purposes.

### Experimental animals and design

Twelve growing male crossbred Boer bucks, eight months old (23.9±1.1 kg average live weight [LW]; mean ± standard deviation) were housed in individual metabolic crates for 21 days (11 days adaptation and 10 days collection). The goats sourced from James Cook University farm which were held as a single group from parturition to eight months old where the experiment started.

Prior to commencement of the experiment all goats were treated for internal parasites (Zolvix monepantel, 1 ml/10 kg LW). Seven days later, faecal egg counts confirmed successful control of internal parasites in all except two goats. These two goats were treated with Q-drench, (1 mL/5 kg LW) and further faecal egg counts throughout the experiment and pre- and post-experiment pack cell volume of blood samples confirmed the absence of internal parasites. Bucks were ranked and blocked (light, medium, heavy) on live weight and randomly assigned to one of four dietary treatments within each live weight block. Dietary treatments were randomly assigned to individual adjacent metabolism crates, within each block.

A randomized block design comprising 4 dietary treatments and 12 bucks (3 bucks per treatment) was utilised. The low number of replicates (n=3/treatment) was used according to the available resources and practicalities in data collection. Dietary treatments were formulated using Rhodes grass hay as the basal diet and supplemented with flaked maize as an energy source, cottonseed meal as an UDP and urea as a RDP source. The four dietary treatments were: Rhodes grass hay + maize (Control), Control + urea (M+U), Control + urea + cottonseed meal (M+UCSM) and Control + cottonseed meal (M+CSM).

The animals were housed in individual metabolism crates at the James Cook University Veterinary Science shed, Townsville (19° 19' 30" S, 146° 45' 44" E) tropical North Queensland, Australia. A basal diet feed trough for Rhodes grass hay was mounted on the side of the metabolism crate where another small bucket for the supplement was also

placed. All experimental animals had ad libitum access to clean, fresh, drinking water and the room was illuminated at night.

**Diet formulation and feeding regime**

Diet was formulated of Rhodes grass hay and supplements that consisting of maize, urea, and cottonseed meal. The Rhodes grass hay was chopped into 5–10 cm size, stored in a barn and fed out to experimental animals in plastic bins. The proportions (g/d) DM basis with which maize, urea and cottonseed were supplied to form each of the supplements was 45.9: 0: 0 (Control), or 46: 0: 140.2 (M+ CSM), or 45.9: 4.1: 0 (M+U) or 45.9: 5.4: 112.3 (M+ UCSM), respectively. The proportion of urea in the M+U and M+UCSM diets was

limited to 1% DMI (Meat and Livestock Australia [MLA], 2013, pp. 59). Urea was ground into a fine powder to mix completely with the maize and/or cottonseed meal according to the dietary treatment.

The concentrations of RDP for Rhodes grass hay were controlled using wet chemistry analysis by the Forage Lab Australia, Victoria, Australia (www.foragelabaustralia.com.au), an affiliate of the Cumberland Valley Assay Service (CVAS), USA. Concentrations of RDP for cottonseed meal, maize and urea were quoted from NRC (2007, pp. 312-329) published values. The nutrient compositions of the dietary treatments are presented in Table 1.

**Table 1. Composition of the control diet of Rhodes grass hay plus maize (Control) and the control diet supplemented with either urea (M+U), urea and cotton seed meal (M+UCSM) or cotton seed meal (M+CSM) fed to growing male crossbred Boer kids**

Parameter	Treatment groups			
	Control	M+U	M+UCSM	M+CSM
DM(g/kgfreshwt)A	890	892	893	894
OM(g/kgDM)A	896	899	900	902
CP(g/kgDM)A	106	175	175	175
UDP(g/kgDM)B	35	34	42	47
RDP(g/kgDM)B	71	141	133	128
ME(MJ/kgDM)B	10.3	10.1	10.3	10.4
<b>Laboratory analysis</b>				
Nutrient	Rhodes grass hay	Urea	Cottonseed meal	Maize
DM (%) <sup>A</sup>	88.8	99.7	91.6	90.9
OM (%) <sup>A</sup>	88.9	99.95	92.8	98.5
CP (%) <sup>A</sup>	10.8	297	52.5	8.8
RDP (%DM)	7.2 <sup>C</sup>	100 <sup>D</sup>	79.8 <sup>D</sup>	94.7 <sup>D</sup>

DM = dry matter, OM = organic matter, CP = crude protein, UDP = undegraded dietary protein, RDP = rumen degradable protein and ME = metabolizable energy A values were from Laboratory analysis at James Cook University, Australia, methods according to AOAC (1990). B values were predicted as the proportions of individual feedstuff multiplied with wet chemistry analysis for Rhodes grass hay or from NRC (2007) for cottonseed meal, maize and urea. C Values from wet chemistry D Values from NRC (2007). The total amount of the basal diet offered was based on average DMI during the 11-d adaptation period. During the collection period, the amount of basal diet offered was adjusted daily based on the average DMI of the two previous days plus 10%, allowing for refusals. The experimental diet was formulated to meet the bucks’ nutrient requirements as per NRC (2007, pp. 282-287) – being DM 810 g, ME 8.2 MJ/d, and RDP 49 g/d. Crude protein in the M+U treatment was lower than recommended as the amount of urea was limited to 1% DMI to avoid ammonia poisoning (MLA 2013). Loose lick minerals (Rumevite® Ferafos) were provided with the supplements and fresh drinking water was freely available.

**Experimental procedures**

Rhodes grass hay was offered *ad libitum* in a feed trough at 08.00 h and 16.00 h. Mixed supplements were separately placed in a plastic bucket and fed twice a day at the same amount prior to offering the basal diet. Daily feed intake and refusals were weighed and recorded to estimate dry matter intake (DMI) to ensure it met the nutrient requirements of the goats.

Individual daily feed refusals were weighed every morning for the duration of the 10-day data collection period. About 10% of the sub-sampled feeds was placed in an airtight sealed plastic container and stored in a cool room at 3°C. At the conclusion of the experiment, the total refused Rhodes grass hay was mixed thoroughly, sub-sampled (50%), oven dried at 60°C and ground twice to pass through a 1.5 mm (Retsch GmbH, West Germany) and 0.1 mm sieve (Retsch cyclone mill, www.mep.net.au), respectively. Feed intake and nutrient intake were presented in Table 2.

**Table 2. Mean values for the intakes of dry matter, organic matter and crude protein and average daily gain for growing male crossbred Boer kids fed Rhodes grass hay plus maize (Control) or the control diet supplemented with urea (M+U), urea and cotton seed meal (M+UCSM) or cotton seed meal (M+CSM)**

Parameter	Treatment groups				sem	P-values
	Control	M+U	M+UCSM	M+CSM		
DMI(g/d)	497 <sup>A</sup>	463 <sup>A</sup>	562 <sup>B</sup>	597 <sup>B</sup>	17.73	0.003
Hay intake (g/d)	451	413	399	411	10.00	0.312
Supplement intake (g/d)	46 <sup>A</sup>	50 <sup>B</sup>	163 <sup>C</sup>	186 <sup>D</sup>	19.30	0.000
Total DMI (g DM/kg LW.d)	22.67 <sup>A</sup>	21.00 <sup>A</sup>	25.00 <sup>B</sup>	25.00 <sup>B</sup>	0.63	0.032
OMI(g/d)	444 <sup>A</sup>	414 <sup>A</sup>	505 <sup>B</sup>	535 <sup>B</sup>	16.35	0.003
CPI (g/d)	56 <sup>A</sup>	69 <sup>B</sup>	121 <sup>C</sup>	130 <sup>D</sup>	1.44	0.000
DMI(%LW)	2.3 <sup>A</sup>	2.1 <sup>A</sup>	2.5 <sup>B</sup>	2.5 <sup>B</sup>	0.04	0.032
ADG(g/d)	77	89	124	108	25.39	0.60

Values in the same row that differ significantly ( $P < 0.05$ ) are indicated by different superscripts DMI = dry matter intake, OMI = organic matter intake, CPI = crude protein intake, ADG = average daily gain, sem = standard error mean and LW = live weight

### Chemical analysis

Proximate analysis (Association of Official Analytical Chemists [AOAC], 1990, pp. 69-88; 312) was conducted to determine dry matter (DM), organic matter (OM), ash, and crude protein (CP) contents of Rhodes grass hay offered and refused, supplements offered and faeces. Representative samples of the basal and supplemental diets were dried at

60°C, over 72 h, cooled, weighed and ground to pass through a one mm sieve using a Laboratory Mill (Thomas Model 4 Wiley® Mill; Thomas Scientific) and analysed using standard methods of AOAC (1990) for DM (g/kg as fed). Organic matter and ash contents were determined after oven-drying and combusting the samples in a furnace at 550°C for four hours.

Total nitrogen in the feed, faeces, and urine were analysed by the Kjeldahl method (AOAC 1990, pp. 69-88). Samples of blank, recovery (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> and standard glycine were run with each analysed batch to ensure there was no carry-over between samples. Estimated nitrogen content was determined by equation 1.

$$g (\%N) = \left( \frac{\text{Normality of acid} \times (\text{mL sample titrant}) - (\text{mL blank titrant})}{\text{Dry weight of sample}(g) \times 10} \right) \times 14.01$$

(Equation 1)

Crude protein (CP) then was calculated as  $CP = N \times 6.25$

were then mixed, sub sampled at 10% and ground to pass through a 1.5 and 0.1 mm sieve for proximate analysis.

### Digestibility and nitrogen retention measurements

A separator under each metabolic crate enabled faecal collection into a plastic bag, while urine was directed into an eight-L plastic bucket containing 5 mL of concentrated H<sub>2</sub>SO<sub>4</sub> to avoid nitrogen evaporation. Each morning after cleaning and feeding, collected faecal matter was mixed thoroughly and one third was oven dried at 60°C. The oven dried faecal samples

Excreted urine was collected every morning, weighed, sub sampled (10% of the total weight), poured into a plastic jar and stored in a cool room at 3°C pending nitrogen analysis. The apparent digestibility coefficient (ADC) of nutrients in the diets was calculated using the equation of McDonald et al. (2011, pp. 237) and Khan, Un-Nisa and Sarwar (2003) as follows:

$$ADC \text{ of nutrient } (\%) = \left( \frac{\text{Nutrient intake } (g) - \text{Nutrient in faeces } (g)}{\text{Nutrient intake } (g)} \right) \times 100$$

(Equation 2)

The unit measurement (%) was then converted into g/kg DM. Digestible nutrients (g/d) were calculated as the difference between the nutrients in the consumed diet and faeces. Estimated MP intake (g/d) was calculated as 0.7 of the

digestible crude protein (NRC 2007, pp. 330). Estimated ME intake (MJ/d) was calculated as suggested in Equation 1.2C by CSIRO (2007, pp. 33) as follows:



$$\left(\frac{M}{D}\right) = (0.194 \text{ DOMD} - 2.58)$$

(Equation 3)

where M/D refers to metabolizable energy (MJ/kg feed dry matter) and DOMD refers to digestible organic matter in dry matter.

Nitrogen retention was calculated as:

$$\text{Nitrogen(N)retention(g)} = \text{Nintake(g)} - (\text{FaecalN} + \text{UrinaryN})(g)$$

(Equation 4)

### Statistical analysis

Feed intake, digestibility and nitrogen retention data were analysed as respondent variables using the univariate of General Linear Model (GLM) (SPSS Statistics for Windows, Version 23.0, IBM Corp. Released 2014, Armonk, NY, USA) with treatments and animal groups as fixed factors. The main effect was adjusted for treatments (P<0.05), while the Post Hoc test was adjusted for treatments and animal groups. The differences between treatments were compared using Duncan’s multiple range test at a P<0.05. The model used for these parameters was  $Y_{ij} = \mu + T_i + B_j + e_{ij}$ ; where  $Y_{ij}$  is the respondent variable,  $\mu$  is the overall mean,  $T_i$  is the treatment effect,  $B_j$  is the animal group or block effect and  $e_{ij}$  is the random error.

### Results and Discussion

#### Feed and nutrient intakes

Daily feed and nutrient (DM, OM, and CP) intakes in the experimental goats are presented in Table 2. All nutrient intakes except DMI and OMI of Rhodes grass hay (RGH), were influenced by protein supplementation (P<0.05). Control goats ate about 9 to 13% more RGH (P<0.05) compared with RGH intake in the supplemented goats. Higher total DMI was recorded in the M+CSM and M+UCSM goats but not evident in M+U goats. This total DMI equated to 2.5% of live weight for the M+CSM and M+UCSM goats compared with 2.3 and

2.1% in Control and M+U groups, respectively. Total OMI was similar to total DMI, where the increases in total OMI for the M+CSM and M+UCSM groups were 21 and 14%, respectively, while those of the M+U and Control goats were similar. Protein supplementation increased total CPI as expected, but there was a significant difference between supplemented groups in the following decreasing order from high to low: M+CSM, M+UCSM and M+U. The inclusion of cottonseed meal, urea plus cottonseed meal and urea increased total CPI by 132, 116 and 23%, respectively, much higher than that in the Control group. It is recorded in the present study that UDP is determining the DMI of growing kids fed tropical grasses.

ADC, digestible nutrient intakes and predicted MP and ME. Apparent digestibility coefficients (ADC) of CP was significantly (P=0.007) higher for goats fed supplements containing additional protein with no difference between the different combinations of protein sources in the supplements (Table 3). Crude protein digested and absorbed by the goats was completely different across all treatment groups; it was highest in M+CSM, followed by M+UCSM, M+U and lowest in the Control diets. The inclusion of cottonseed meal only or urea plus cottonseed meal gave the same results with regard to digestible DM and OM intakes. Urea supplement did not affect digestible DM and OM intakes. The three protein supplements increased estimated MP intake, but the estimated ME intake was increased by M+CSM and M+UCSM supplements.

**Table 3. Apparent digestibility (g/kg DM), digestible nutrient intakes (g/d) and estimated intakes of metabolizable protein (g/d) and metabolizable energy (MJ/d) in growing male crossbred Boer kids fed the control diet of Rhodes grass hay plus maize (Control) or the control diet supplemented with urea (M+U), urea plus cottonseed meal (M+UCSM) or cotton seed meal (M+CSM)**

Parameter	Treatment groups				sem	P-values
	Control	M+U	M+UCSM	M+CSM		
	<b>Apparent digestibility</b>					
DM (g/kg DM)	595	595	618	622	29.88	0.39
OM (g/kg DM)	622	624	648	653	28.19	0.33
CP (g/kg DM)	668 <sup>A</sup>	733 <sup>B</sup>	773 <sup>B</sup>	769 <sup>B</sup>	23.35	0.01
	<b>Digestible nutrient intakes</b>					
DM (g/d)	295 <sup>A</sup>	273 <sup>A</sup>	345 <sup>B</sup>	370 <sup>B</sup>	10.65	0.00
OM (g/d)	275 <sup>A</sup>	256 <sup>A</sup>	326 <sup>B</sup>	349 <sup>B</sup>	9.34	0.00

CP (g/d)	37 <sup>A</sup>	50 <sup>B</sup>	93 <sup>C</sup>	100 <sup>D</sup>	1.25	0.00
	<b>Estimated intakes of MP and ME</b>					
MP(g/d)*	26 <sup>A</sup>	35 <sup>B</sup>	65 <sup>C</sup>	70 <sup>D</sup>	0.82	0.00
ME(MJ/d)**	9.5	9.5	10.0	10.1	0.38	0.59

DM = dry matter, OM = organic matter, CP = crude protein, sem = standard error mean, MP = metabolizable protein and ME = metabolizable energy

\*Estimated intake of MP was calculated as 0.7 of the digestible crude protein (NRC 2007).

\*\*Estimated intake of ME was calculated as  $M/D = 0.194 \text{ DOMD} - 2.58$  (CSIRO 2007) Eq. 1.12C, where M/D refers to metabolizable energy (MJ/kg feed dry matter) and DOMD refers to digestible organic matter in dry matter.

Values in the same row which differ significantly ( $P < 0.05$ ) are indicated by different superscripts

**Excreted faeces and urine, nitrogen intake and retention**

**Table 4. Excreted faeces and urine, intake of nitrogen and nitrogen retention in growing male crossbred Boer kids fed the control diet of Rhodes grass hay plus maize (Control) or the control diet supplemented with either urea (M+U), urea and cottonseed meal (M+UCSM) or cottonseed meal (M+CSM)**

Parameter	Treatment groups				Sem	P-values
	Control	M+U	M+UCSM	M+CSM		
Nitrogen intake(g/d)	8.8 <sup>A</sup>	10.8 <sup>B</sup>	19.3 <sup>C</sup>	20.8 <sup>D</sup>	0.22	0.00
Faecal excretion(g/kgDM)	202	185	213	226	15.32	0.35
Urinary excretion(g/d)	574	522	788	575	78.88	0.16
Nitrogen in faeces(g/d)	2.9 <sup>A</sup>	2.9 <sup>A</sup>	4.3 <sup>B</sup>	4.8 <sup>B</sup>	0.22	0.00
Nitrogen in urine(g/d)	4.6 <sup>A</sup>	4.8 <sup>A</sup>	11.3 <sup>B</sup>	10.8 <sup>B</sup>	0.34	0.00
Nitrogen retention(g/d)	1.3 <sup>A</sup>	3.1 <sup>B</sup>	3.7 <sup>B</sup>	5.2 <sup>C</sup>	0.33	0.00

Values in the same row which differ significantly ( $P < 0.05$ ) are indicated by different superscripts

DM = dry matter; sem = standard error mean

The increased total DMI in the M+CSM and M+UCSM goats emphasized the relationship among protein supplements, feed

intake and digestibility. Solomon et al. (2008) found that total intakes of feed and nutrients and digestibility of nutrients are linearly correlated with an increase in cottonseed supplement. Lu and Potchoiba (1990) demonstrated that feed intake has a positive linear relationship with dietary protein content. This relationship could be used to explain the finding in the present study where total DMI in the M+UCSM and M+CSM goats was partly due to nitrogen availability. In contrast to low DMI of M+U goats, this finding suggests that a respon to a NPN source only accures at much lower CP content.

As the goats are offered more protein, proteolytic rumen microbes, instead of cellulolytic or fibrolytic microbes, are likely to be actively degrading the ingesta (Bach, Calsamiglia and Stern, 2005), therefore, CP digestibility increases but not

The quantity of excreted faeces and urine was not significantly ( $P > 0.05$ ) different for goats fed supplements containing additional protein (Table 4). The addition of cottonseed meal or urea plus cottonseed meal doubled nitrogen intake in goats fed urea supplement or basal diet only. Similarly, nitrogen excretions in the M+CSM and M+UCSM goats were twice as high as in the other two groups. Urinary nitrogen in all treatments was almost twice as high as faecal nitrogen. As expected, all three protein supplements caused a significant increase of nitrogen retention ( $P < 0.05$ ). Despite nitrogen excretion between the M+CSM goats and the M+UCSM goats being similar, nitrogen retained in M+CSM goats was significantly higher than that in M+UCSM goats. The M+UCSM goats had a higher nitrogen intake compared to M+U goats, but because nitrogen excretion followed a similar pattern, nitrogen retention in the two groups were similar.

DM and OM digestibility. This increased CP digestibility provides more space available in the digestive tract, which promotes feed intake (Jones, 1972).

The highest total DMI in the M+UCSM and M+CSM groups in the present study showed that protein supplementation originating from cottonseed meal resulted in increased intake. This finding agreed with previous studies (Yinnesu and Nurfeta, 2012) that reported an increased total DMI when protein-source supplements were added to the diet. Cottonseed meal in the current study seems to increase total DMI as evidenced by the 13.07% and 16.75% increase in total DMI in the M+UCSM and M+CSM groups compared to that of Control or 21.38% and 28.9% in both groups higher than that for the M+U groups, respectively. The similar hay intake (Table 2) in the current study was in contrast to the report by Solomon et al. (2008) who found a decreased hay intake in Sidama goats due to an increased in cottonseed meal intake.

It is more likely that the goats increase the grass intake to meet the energy and protein requirement for both rumen microorganisms and the goats. The Control and M+U goats could have increased RGH intake to meet their energy and protein requirements, but the gut-fill effect from the reticulo-rumen (Allen, 1996) limited dry matter intake. Fibrous feeds

are usually ruminated and fermented slowly, staying in the rumen longer (Morand-Fehr, 2005), and preventing the animal from eating more.

The low total DMI of the M+U goats is consistent with a previous study by Wambui et al. (2006). Bach et al. (2005) explained that there is an energy cost for over-supplied RDP such as urea to be converted into ammonia, absorbed, metabolised, and excreted in urine. Unless sufficient energy is available (Uza et al., 2005; Patterson et al., 2009), the goats lose weight, as demonstrated by Wambui et al. (2006), which could be as a consequence of tissue energy mobilisation. Therefore, the low DMI of the M+U goats in the current study is a normal physiological behaviour of goats to avoid severe body weight loss.

The lack of difference in DM and OM digestibilities was possibly related to feed characteristics and animals eating selectivity. The goats on the basal diet only, may have selected the leafy grass hay (Lu, 1988) with low fibre, hence an increase in digestibility (Hall and Eastridge, 2014). However, the inclusion of cottonseed meal and urea plus cottonseed meal benefitted the goats more because of higher feed intake, and consequently, significant amount of DM, OM, and ME was available to the goats. This finding could be explained by the fact that cottonseed meal was a medium for fibrolytic rumen microbes (Varga and Kolver, 1997) to digest hemicelluloses and celluloses and become energy sources (Hall and Eastridge, 2014). Another possible explanation is that cottonseed meal, being rich in fermentable energy (Hall and Eastridge, 2014), was readily available for the rumen microbes and the goats to utilize. No difference organic matter digestion between low and high protein diets in current study was similar to the study of Ash and Norton (1987) in Australian Cashmere goats. This finding might be related to digestion process to the organic matter components where fibre digestion for the four diets took place in the rumen. Further more, nitrogen was more available in the rumen when goats fed high protein diet, while non ammonia nitrogen more available in the small intestine when goats fed low protein diet (Ash and Norton, 1987).

The observation that an inclusion of cottonseed meal only or mixed with urea increased CP digestibility and supplied more CP and MP to the goats was consistent with previous studies (Solomon et al., 2008; Alemu et al., 2010). This can be explained by the function of cottonseed meal and urea as high-protein feed supplements. Rumen microbes degrade dietary intake protein into peptides, amino acids and ammonia to meet the requirements of rumen microbes (Bach et al., 2005). High degradability in the rumen leads to more nutrients being absorbed in the small intestines, hence the higher digestibility recorded. When flowing into the abomasum and small intestines, rumen microbes become microbial crude protein that contributes to MP (AFRC, 1993).

The higher digestible CP and predicted MP in the M+CSM goats as compared with that in the M+UCSM and M+U goats, could be linked to feed intake and degradable protein characteristics of the feeds. As a cause-effect relationship, goats that eat more and have higher digestibility are expected

to have higher digestible nutrient intake. Regarding degradability, Mishra and Rai (1996) found that increasing the intake of rumen UDP, such as cottonseed cake, increased CP digestibility. Therefore, the higher CP digestibility in the present study was due to cottonseed meal being a source of UDP feeds. Urea as a high RDP, on the other hand, would have been highly degraded by rumen microbes, becoming ammonia (Bach et al. 2005), but because energy was limited, ammonia was excreted through faeces and urine as nitrogen.

The higher quantity of retained nitrogen in the supplemented goats demonstrates the benefit of protein-source feeds supplying nitrogen or protein to the goats. However, the higher retained nitrogen in the M+CSM goats than those in the M+UCSM and M+U goats indicates that UDP was better than RDP, a similar observation in other reports (Solomon et al., 2008; Wang et al., 2012). The highest nitrogen retention was also confirmed by the highest predicted intakes of MP in the M+CSM goats. A similar explanation by Bach et al. (2005) was that cottonseed meal would be less degraded by rumen microbes to ammonia, the UDP of cottonseed meal would be readily absorbed in the small intestines, hence more nitrogen retained in the goats. Some workers had optimised the usage of RDP e.g. urea to enhance retained nitrogen by mixing urea with dextrose (Patterson et al., 2009) or to reduce the degradation of high RDP, such as soybean meal treated with formaldehyde (Al Jassim et al., 1991).

The predicted MP supply in the current study was most likely sufficient for the goats to gain weight of about 83 or 92 or 9 g/d for the M+UCSM; M+CSM and M+U goats, respectively, while the Control goats lost weight (Sahlu et al., 2004). Average daily gain, however, as shown in Table 2 causes all goats to gain weight, which might be due to sufficient predicted metabolizable energy available as suggested by Sahlu et al. (2004). The ADG in this study, however, was unreliable for the study was not designed for that purpose.

## **Conclusion**

Cottonseed meal supplementation increased total DMI, nutrient intakes, crude protein digestibility, predicted MP and nitrogen retention in meat goats on Rhodes grass hay basal diet although the diets were isonitrogenous with protein supplementation origin from urea or urea plus cottonseed meal. Put together, our results provide definitive empirical data supporting protein supplementation based on RDP and UDP content of the dietary supplement.

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