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Effect of replacement of soybean meal with urea or urea supplemented with sulphur on the performance of lambs

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Abstract: The objectives of the study were to determine the effect of the replacement of soybean meal (SBM) with urea (U) or urea supplemented with sulphur (US) on the performance of lambs. Twelve lambs were allocated to one of three dietary treatments in a completely randomized design. Control lambs were offered SBM diet with Guinea grass as the basal ration while lambs that received either of the other two treatments were offered the same basal ration with the replacement of SBM with either U or US. Dry matter (DM) intakes (g/d), DM digestibility, microbial protein supply and purine derivative excretion were higher ($p<0.05$) in SBM and US than U. Concentrate, energy and digestible OM intakes, organic matter (OM) digestibility, energy concentration, ratio of digestible energy to digestible crude protein and OM digested in the rumen were greater ($p<0.05$) in SBM than U or US. N free extract digestibility and urinary N were higher ($p<0.05$) in U or US compared to SBM. Though there was no ($p>0.05$) treatment effect on average daily gain and feed conversion ratio, they tended to be lower ($p=0.07$) in U than SBM or US. In conclusion, the replacement of SBM with U or US can be achieved without affecting the performance of the lambs.
Keywords: Apparent digestibility, Lambs, Microbial protein supply, N utilization, Non-protein N, Purine derivative excretion, Weight gain

INTRODUCTION

High cost and scarcity of conventional feedstuffs constitute major problems facing commercial livestock production in developing and underdeveloped countries [1]. Therefore, unconventional ingredients as a source of protein are strategic for sustainable ruminant production due to a keen competition between humans and livestock for conventional feed ingredients. The key to economic and sustainable livestock production lies in the replacement of expensive feedstuffs with less expensive ingredients of no feeding value to humans. The use of groundnut cake and soybean as protein sources in livestock diets has resulted in the increasing cost of production and livestock products. Corollary to this, the need to find alternative and cheaper ingredients to replace the expensive ones is inevitable. Studies [2-4] have indicated urea can replace the conventional protein sources.

Urea has been used extensively in ruminant nutrition a source of non-protein N. In rumen, many fiber-digesting bacteria require ammonia for protein synthesis [5]. Protein requirements are provided by microbial protein and rumen escape dietary protein [6]. Urea is commonly added to ruminant diet as a source of non-protein nitrogen that is rapidly hydrolyzed to ammonia in the rumen. Hence in view of the serious shortage of natural proteins in Nigeria, it appears feasible to use urea in livestock diet.

Ruminants have a highly efficient anaerobic fermenter located at the beginning of their digestive tract. This allows them to digest fibrous feed and to use non-protein N (NPN) to synthesize microbial matter, thereby reducing their competition with humans for food. Providing supplementations with a high concentration of true protein to ruminants fed low-quality roughage stimulates roughage intakes, digestion, and performance [7, 8]. However, substituting non-protein N (NPN) such as urea has been shown to increase voluntary feed intakes [9, 10], which is generally attributed to an improvement of nutrients digestibility and an increased passage from the rumen. Sulphur is utilized by ruminants to synthesize sulphur-based amino acids. Therefore, urea supplementation with S may further improve the nutritive value of urea. From the foregoing, a study was thus conducted to determine the voluntary intakes, feed efficiency, microbial protein supply, digestibility, purine derivative excretion, N utilization and growth performance of lambs fed rations in which soybean meal was replaced with urea with or without S.

MATERIALS AND METHODS

The experiment was conducted at the Sheep Unit of the Teaching and Research Farm University of Ibadan, Ibadan. The location is 7° 27'N and 3° 45'E at altitude 200 - 300 m above sea level. The climate is humid tropical with mean temperature of 25-29°C and the average annual rainfall of about 1250 mm.

Animal, diets and experiment procedure

Twelve West African dwarf sheep (6 ram and 6 ewe lambs, 7-month-old; 7.2 ± 0.3 initial live weight (LW)) stratified into three groups of four animals (2 ram lambs and 2 ewe lambs) of similar LW each were randomly assigned to one of three treatment diets in a completely randomized design. The lambs, housed individually in clean, semi-open and concrete-floored pens, were quarantined for two weeks during which they were treated with Pestis de Petit Ruminantum vaccine, antibiotics (oxytetracycline), dewormer (levamisole) and dipped in diazintol solution. The floor was bedded with softwood shavings. They were placed on the treatment diets during this period. Three iso-nitrogenous diets (170 g/kg CP; DM basis) containing soybean meal (SBM) as the true or conventional protein source, SBM replaced with urea (U), as non-protein N source, and urea supplemented with elemental sulphur (US) as another protein source for replacing SBM were formulated (Table 1). The experimental diets, fed once daily at 09:00 h, was offered at 3% of the animals' LW while the basal diet, fresh forages of Guinea grass (*Panicum maximum*) were offered *ad libitum* throughout the experiment. An adaptation period of 2 wk, which ran concurrently with the 2 wk quarantined period, was allowed prior to the experimental period which lasted 9 wk comprising 8 wk growth trial and 1 week metabolism trial. Feed refusals were removed and weighed daily throughout the study. The DM and nutrient (CP and organic matter (OM)) intakes were measured daily on DM basis. Lambs were weighed at the beginning of the experiment and then weekly throughout.

Table 1: Ingredient composition (g/kg) and chemical analysis of the experimental diets

	Soybean meal	Urea	Urea + S	*P. maximum*
Corn bran	780	958	955	
Soybean meal	200	-	-	
Urea	-	22	22	
Sulphur	-	-	3	
Oyster shell	7.5	7.5	7.5	
Bone meal	5.0	5.0	5.0	
Salt	5.0	5.0	5.0	
Vitamin-mineral premix*	2.5	2.5	2.5	
Chemical analysis				
Dry matter	899	892	896	332
Nutrient (g/kg DM)				
Crude protein	174	170	172	128
Organic matter	952	950	951	879
Crude fibre	127	136	135	340
Ether extract	29.6	26.0	25.5	33.9
Ash	47.6	49.8	48.6	121
Nitrogen free extract	622	618	619	377

*supplied the following per kg of complete diet:
Vitamin A 4,000,000 IU; Vitamin D3 2,000,000 IU; Vitamin E 7,000 IU; Vitamin B2 4,000 mg; Nicotinic acid 15,000 mg; Calcium D-pentothenate 8,000 mg; Biotin 40 mg; Vitamin B12 10 mg; Mn 20,000 mg; Fe 50,000 mg; Zn 100,000 mg; Cu 10,000 mg; Iodine 750 mg; Co 3,000 mg.

At the end of the growth experiment, the lambs from each group were housed individually in metabolism crates to determine apparent digestibility and N utilization. Lambs were allowed a period of 10 d to adapt to the crates followed by a collection period of 7 d when feed intakes and orts were recorded and sampled. Daily faecal and urinary output of each animal were collected, weighed, and recorded, and then 10% each was kept. At the end of the experiment, samples from each lamb were mixed and a subsample for both faeces and urine analysis obtained. N loss from urine was prevented by adding 2 ml of concentrated H_2SO_4 solution into the each urine collection container. These were later frozen until needed for analysis.

Laboratory analysis

Samples of concentrate, *P. maximum* foliage and faeces were ground through a 1-mm screen prior to analysis and were later analyzed for their proximate constituents according to the methods of AOAC [11]. Estimated microbial protein synthesis (MPS) and urinary purine derivative excretion (PDE) were calculated using the equations of Chen and Gomes [12].

Microbial N yield (MN) = 32 g/kg x digestible organic matter fermented in the rumen (DOMR),

where
DOMR= DM intake × OM content × OM digestibility × 0.65

Total purine excretion (PD_e) (mmol/d) = 0.84 purine absorbed (P_a) + 2, where

Purine absorbed (P_a) (mmol/d) = MN (g N/d) ÷ 0.727

Statistical analysis

Data were analyzed by the analysis of variance (ANOVA) techniques using the general linear model (GLM) procedures of the SAS (13). Treatment means were compared by Duncan multiple range test and results were considered significantly different when p<0.05 and a tendency when p<0.10.

RESULTS AND DISCUSSION

The supplementary concentrate diets had parallel nutrient profile while the CP content was higher than the recommended value of 145 g/kg for growing sheep (14). The chemical composition of the basal forage, *P. maximum*, is consistent with the previous findings [15-17]. The relatively high level of CP and low level of fibre in Guinea grass suggest its suitability for sheep, in terms of feed intake and digestibility, which have a limited rumen capacity to use highly lignified feeds. Nevertheless, the nutritive value of Guinea grass may depend on cultivar, age of plant, plant density, the plant part, soil fertility, harvesting frequency, season and climate.

Table 2: Feed intake and performance characteristics of lambs fed soybean meal (SBM) diet replaced with urea (U) or urea plus S (US) diet

	SBM	U	US	SEM	P-value
Intake (g/d)					
Forage:concentrate	73:27	76:24	75:25		
Forage	441	417	437	5.35	0.212
Concentrate	166[a]	129[b]	147[ab]	11.5	0.04
Total	607[a]	546[b]	584[a]	59.6	0.02
Dry matter intake, g/kg $W^{0.75}$	97.3	92.2	95.7	4.79	0.97
Dry matter intake, g/kg BW	52.8	51.0	52.4	2.80	0.859
Crude protein intake, g/kg $W^{0.75}$	13.7	12.7	13.3	0.94	0.423
Organic matter intake, g/kg $W^{0.75}$	87.4	82.6	85.9	3.87	0.65
Average daily gain, g/day	92.9	67.9	80.4	14	0.068
Feed conversion ratio	6.53	8.04	7.26	0.007	0.072

Means on the same row with the same letter are not significantly different (p>0.05).

Table 3: Apparent digestibility and nutritive value in lambs fed soybean meal (SBM) diet replaced with urea (U) or urea plus S (US) diet

Apparent digestibility (g/kg)	SBM	U	US	SEM	P-value
Dry matter	757[a]	701[b]	746[a]	15.1	0.044
Crude protein	762	794	750	5.56	0.156
Crude fibre	601	622	583	17.4	0.456
Ether extract	748	716	728	5.90	0.178
Nitrogen free extract	728[b]	825[a]	799[a]	1.40	0.017
Organic matter	811[a]	729[b]	757[b]	19.5	0.016
Nutritive value (g/kg $W^{0.75}$)					
Digestible dry matter	58.8	55.2	57.8	3.52	0.787
Digestible organic matter	117	110	111	4.63	0.859
Digestible crude protein	17.2	18.3	17.1	1.20	0.654
Digestible energy (MJ/kg DM)[1]	14.1[a]	12.6[b]	13.0[b]	0.38	0.044
Metabolizable energy (MJ/kg DM)[2]	11.6a	10.4[b]	10.7[b]	0.32	0.038
DE/DCP (MJ/g)[3]	0.82[a]	0.69[b]	0.76[b]	0.04	0.03

Means on the same row with the same letter are not significantly different (p>0.05).
[1]Digestible energy (Mcal) = 0.22 kg digestible organic matter (DOM) NRC [32]
[2]Metabolizable energy (Mcal/kg) = 0.82 x DE Mcal/kg NRC (32)
[3]DE/DCP: digestible energy:digestible crude protein ratio

Table 4: Plane of nutrition of lambs fed soybean meal (SBM) diet replaced with urea (U) or urea plus S (US) diet

	SBM	U	US	SEM	P-value
Digestible DM intake, g/kg $W^{0.75}$	17.9	15.7	17.3	1.32	0.223
Digestible CP intake, g/kg $W^{0.75}$	5.98	6.07	5.94	0.84	0.346
Digestible OM intake**,** g/kg $W^{0.75}$	42.3^a	37.9^b	39.7^b	1.12	0.048
Organic matter digested in rumen, g/d	172^a	146^b	158^a	8.67	0.037
Digestible energy intake, MJ/d	8.55^a	6.90^b	7.62^a	0.40	0.021
Metabolizable energy intake, MJ/d	7.01^a	5.66^b	6.24^a	0.31	0.024

Means on the same row with the same letter are not significantly different (p>0.05).

Table 5: **N utilization, microbial protein synthesis and purine derivative of lambs fed soybean meal (SBM) diet replaced with urea (U) or urea plus S (US) diet**

	SBM	U	US	SEM	P-value
N intake	14.2	12.8	13.4	1.86	0.269
Faecal N	2.64	1.91	1.96	0.58	0.198
Urinary N	2.92^b	3.86^c	3.74^b	0.30	0.025
N absorbed	11.6	10.9	11.5	1.03	0.856
N balance (g/d)	8.64	7.03	7.80	0.98	0.457
N balance (g/kg $W^{0.75}$)	1.38	1.19	1.28	0.09	0.380
N retention					
g/kg N intake	60.8	54.9	58.2	4.62	0.245
g/kg N absorbed	74.5	64.5	67.8	4.74	0.573
Purine derivative excretion, mmol/d	8.34^a	7.40^b	7.82^a	0.87	0.0312
Microbial protein synthesis					
g/d	34.1^a	29.2^b	31.5^b	1.02	0.023
g N/kg dry matter intake	8.74	8.12	8.40	0.59	0.776

Means on the same row with the same letter are not significantly different (p>0.05).

All the lambs fed urea with or without S diets were in good health throughout the trial as there were no obvious cases of urea and sulphur toxicity. Total DM intake (g/d) was lower (p<0.05) in U compared to SBM or US, which had similar intake. However, when expressed as metabolic weight and LW (g/kg $W^{0.75}$ or g/kg LW), it was not affected by the protein sources. Similarly, intakes of CP, OM and fibre were similar (p>0.05) among the diets. There are conflicting reports on effect of replacing true protein with NPN with or without S on nutrients intake. While Lana *et al*. [18] and Silva *et al*. [19] reported lower feed intake when conventional protein was replaced with urea, Aquino *et al*. [20] reported no effect of true protein replacement with NPN. Similarly, Sinclair *et al*. [3], Gonçalves *et al*. [4] and Chanjula and Ngampongsai [21] indicated no difference in DM, CP, fibre fraction, OM and total digestible nutrient intake when true protein was replaced with urea. Burque *et al*. [22], however, reported both non-significant and significant DM intake with increasing level of urea as replacement for cotton seed cake. Concentrate intake was decreased (p<0.05) by urea with or without S possibly due to less palatability, in agreement with earlier experiment [2, 18, 19]. There was no (p>0.05) effect of treatment on average daily gain and feed conversion ratio, but there was a tendency (p=0.07) for increased ADG and FCR with SBM or US compared with urea. The ADG of lambs fed SBM and US was 36.8 and 18.4% respectively higher than that of lambs fed urea. It appears that supplementation of urea with S had the tendency to improve feed utilization and ADG better than urea only. Sulphur, being a precursor for the other S-containing amino acids [23], improved the quality of synthesized microbial protein or amino acid. It was shown by Ferreiro *et al*. [24] that addition of as little as 1 g ammonium sulphate per kg of fresh sugar cane improved significantly daily gain on a ration composed otherwise of only sugar cane and urea. Brito and Broderick [25] observed reduced feed efficiency as a result of SBM replacement with urea.

Apparent DM digestibility of U was inferior (p<0.05) to that of SBM and US. This is contrary to the results of Goncalves *et al*. (4) and Chanjula and Ngampongsai (21), who observed no significant difference in DM digestibility when SBM was replaced with urea. Variations in results could be due to difference in diet composition and the quality and level of urea used. Nitrogen free extract digestibility was greater (p<0.05) in U or US (p<0.05) than SBM possibly because of increased need for readily fermentable carbohydrate for efficient urea utilization. For efficient utilization of urea for protein synthesis by rumen, microbes, there is the need for availability of readily or soluble carbohydrate. Apparent OM digestibility was superior ($p<0.05$) in SBM compared to urea with or without S supplemented diets. Since OM digestibility is a good indicator of caloric value of feed, therefore the results of the DE and ME concentration showed the same trend as that of OM digestibility. Higher energy concentration of SBM indicates it supplied more energy than urea with or without S supplementation but this did not translate into significantly improved nutrient utilization and growth of the lambs. The results contradict that of Bhattacharya and Pervez [2], who observed no difference in the ME as a result of replacement of SBM with urea. Urea with or without S supplementation, as a SBM replacement, did not ($p>0.05$) influence the CF or CP digestibility, in agreement with earlier reports [2, 3]. Parallel ($p>0.05$) digestible DM, CP and OM among the diets indicate that the nutritive value of urea with or without S supplementation is not inferior to that of SBM and addition of S to urea did not improve its nutritive value compared to urea only. Lower ($p<0.05$) DE/DCP ratio of the urea with or without S supplementation relative to the control diet indicates the diets required less DE per unit of DCP for optimization of feed utilization. Olafadehan *et al*. [1] earlier attributed higher DE/DCP ratio to higher requirement of DE per unit of DCP for optimum feed utilization.

Digestible DM and CP intakes showed the same trend as the digestible DM and CP. Generally, digestible nutrient intake is a function of apparent nutrient digestibility and dry matter intake. Higher ($P<0.05$) intakes of digestible OM, OMDR and energy of SBM is the consequence of its greater apparent OM digestibility and energy concentration relative to urea with or without S supplementation in consistent with previous studies [1], who attributed improved intakes of OMDR, energy and digestible nutrients to greater digestibility of CP and OM, N utilization and energy concentration of the diet.

The insignificant ($p>0.05$) difference in the amount of faecal N, N intake and retained and quantity of nitrogen retained relative to that consumed or that absorbed among the diets was in support of earlier reports [2, 21]. It is now well established that nitrogen retention depends on the intake of nitrogen, amount of fermentable carbohydrate of the diet [26]. Higher ($p<0.05$) urinary N excretion in urea diet could be due to rapid degradation of urea by rumen microbes to produce excess NH_3-N which is absorbed and excreted in the urine in the form of urea. Souza et al. [27] reported that bucks fed urea-supplemented diets excreted more urinary N than those fed natural proteins. It appears that urea supplementation with S helps in improving urea metabolism in the rumen which possibly accounts for reduction in urinary N excretion.

Microbial protein supply ($p<0.05$) was increased by SBM and US because they provided more DOM intake, OMDR and energy for microbial growth [28] than U. Though the energy level was not ($p>0.05$) significant between U and US, it appears that the relatively low energy level of urea resulted in reduced energy availability for incorporation of NH_3-N into microbial protein. Similarly, greater MPS to the small intestine in SBM or US suggests they promoted better synchronization of the available fermentable energy and degradable N in the rumen, in consonance with previous studies [1, 29, 30]. Higher ($p<0.05$) estimated urinary PDE in SBM and US may be due to greater MPS. Agle et al. [31] attributed increased PDE to enhanced MPS outflow from the rumen.

CONCLUSION

The replacement of soybean meal with urea or urea plus sulphur showed that these sources of N are products that can be supplied without performance impairment for sheep.

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