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The Effects of Nitrogen sources in the concentrates on N utilization and production performances of dairy goats

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ABSTRACT: Studies in young goats showed that feeding different N supplements did not significantly affect growth rate, rumen digestion, or N metabolism. It is unclear whether this finding is also applicable to lactating dairy goats. This study aimed to evaluate the efficacy of combinations of barley meal with soybean meal, cottonseed meal, or urea in high energy concentrate on nutrient digestion, milk-feed efficiency, milk production, and Nitrogen balance in dairy goats fed on barley hay as a basal diet. Four isoenergetic and isonitrogenous concentrate with different N sources were formulated and fed on lactating Saanen goats in a 4 x 4 Latin square design. The results showed that lactating Saanen goats producing 1.3 to 1.5 litre of milk per day and fed on a concentrate containing 1.7 % N in a high energy diet capable to sustain similar milk protein and N balance as that given concentrate with 2.2 % dietary N. Total nutrient intakes, nutrient digestion, milk-feed efficiency and milk production lactating Saanen goats was not affected by the source of dietary N. The results indicate that including urea in a supplement can maintain a similar level of milk yield, milk protein and milk efficiency in goats as can the feeding of more expensive soybean and cottonseed meals provided there is sufficient readily available dietary energy.

Keywords: Saanen goat; Dietary N sources; Milk Production; Digestibility; N balance

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INTRODUCTION

Dairy goats have long been considered an essential source of high-quality food and income for rural communities. They are easily adaptive to the environment because of their unique eating behavior. They have become a well-known farm animal in various environments, from temperate grasslands to subtropical, semi-arid, and mountainous areas (Cannas et al., 2007). In addition, goat milk and its products of yogurt, cheese, and powder play a significant role in feeding more starving and malnourished people than cow milk (Haenlein, 2004). However, milk production from goats in developing countries is lower than the genetic potential of the goats because of inadequate dietary protein and energy intake from available forages (Rosartio et al., 2015).

The feeding value of many tropical feeds can be improved by dietary protein supplementations, increasing energy and protein utilization (Schmidely & Andrade, 2011). However, feeding nitrogen supplements for milk production by goats varied depending on the density of energy used in experimental rations and the types and levels of dietary nitrogen (Supriyati et al., 2016)(Supriyati et al., 2017).

Results of our previous studies showed that there were no responses in growth rate, rumen digestion or N metabolism when goats were fed different dietary N supplements (barley meal either with soybean meal, cotton seed meal or urea (A. Rai Somaning Asih & Young, 2012; A. R.S. Asih et al., 2011). These results suggest that urea can be used as a good N source for growing goats. It is unclear whether this finding is also valid for milk production from dairy goats.

The study aimed to determine the effectiveness of combinations of barley meal with soybean meal, cottonseed meal, or urea in high energy diets on total nutrient intakes, nutrient digestion, milk-feed efficiency, milk production, and Nitrogen balance in late lactating Saanen goats.

MATERIALS AND METHODS

Diets

Four isoenergetic (12.6 MJ/kg DM) concentrate mixtures were formulated for milking goats. The negative control concentrate contained barley meal (BM) only. The nitrogen (N) supplemented concentrates were BM plus soybean meal (BSBM), barley meal plus cottonseed meal (BCSM), and barley meal plus urea (BU). All concentrates were isonitrogenous with 2.7 % N, except for BM, which contained 1.7 % N. Barley meal contributed 57 to 59% of total N in the three concentrates. The energy content of the concentrates was adjusted by adding vegetable oil to achieve near equal metabolizable energy content (Table 1).

The daily rations offered were 50 % barley hay and 50 % concentrate. The total ratio offered was based on the amount consumed during preliminary observations. The rations were offered twice daily at 09:00 and 17:00 h. A mineral block designed for goats (Go-Block, manufactured by Olsson Industries Pty Ltd. Brisbane, Australia) and freshwater were available *ad libitum*.

Animals

Four late (2 to 2.5 months post kidding) lactating Saanen goats with an average initial body weight of 71.7 ± 4.9 kg (x ± SD) were penned in individual cages. The initially 2.0 to 2.5month post kidding does were selected for the study to avoid the rapid changes in milk production that occur in early lactation. According to (Badamana & Sutton, 1992), rapid changes in milk yield and composition, and live weight for British Saanen goats occurred in the first five weeks of lactation. The goats were allowed an adjustment period of 2 weeks, during which time they were all fed the same diet of barley hay and concentrate containing an equal amount of BSBM, CSBM, and BU mixture. The purpose of the adaptation period was to stabilize body condition and accustom the goats to eat the diets in the experimental situation. In addition, all goats were treated at the start of the study with ***Ivermectin***

(0.2mg /kg BW Invermectin: Ivomec; Merk, Sharp and Dohme (Australia) Pty. Ltd.) to minimize intestinal parasites.

Design and Experimental Procedure

A Latin square design (4x4) was used for the experiment, which consisted of four periods of 6 weeks duration when the N balance was recorded. Except for period I, the duration of the N balance was recorded for four weeks (it was commenced in the third week). The N balance data was collected for six days of each week. On the seventh day of each week, the goats were exercised for 6 hours in a small group pen to satisfy the requirements of experimental animal ethics when the N balance was not recorded. The data collected during the sixth week of each period were statistically analyzed to determine the effect of different nitrogen dietary supplements.

Table 1. Composition of concentrate supplements (dry matter basis)

	P_0	P_1	P_2	P_3
Composition (%)				
Barley meal	89.0	83.5	82.0	86.3
Soybean meal	-	16.5	-	-
Cottonseed meal	-	-	17.8	-
Urea	-	-	-	2.5
Vegetable oil	3.5	-	0.2	3.5
Sugar	7.5	-	-	7.7
Chemical composition				
DM (%)	92.49	91.74	91.56	92.38
Nitrogen (%)	1.65	2.82	2.75	2.82
ME (MJ/kg)	13..92	13..45	13.30	13.77
NDF (%)	17.18	18.63	21.15	16.39
ADF (%)	4.82	6.09	8.31	4.64
Hemicellulose (%)	12.37	12.54	12.93	11.74

P0 = barley meal (BM) only, P1=BM + Soybean meal (BSBM), P2= BM+cottonseed meal (BCSM), P3= BM+ Urea (BU), DM= dry matter; ME= metabolisable energy; NDF = neutral detergent fibre; ADF = Acid detergent fibre.

Measurements

The goats were machine-milked once a day at 8:00 h, and milk samples were taken for N analysis. Body weights were measured weekly immediately after milking and before the morning feeding. Daily intake of hay and concentrate was determined by subtracting refusals from the amount offered. The refusals of hay and concentrate were separated for later analysis. Dry matter (DM), N, and the intake of fiber components of both hay and concentrate were calculated from the chemical analyses, and daily feed was offered and refused.

Sampling Methods

Feed samples were taken from each batch. For later chemical analysis, refusals from each animal were sampled daily and pooled over three-day periods. Nutrient digestibility and N balance measurement (N intake minus fecal, urine, and milk N output) were made daily, except for the exercise days. Each animal's total daily fecal output was measured. A 20 % sub-sample was collected every day, dried in a forced draught oven at 59^0 C, and then ground to 1mm particle size before the chemical analysis.

Daily urine was collected from each animal into a plastic container containing glacial acetic acid (50 ml) to retain nitrogen and maintain the pH below 3. Ten percent sub-sample of urine was frozen and stored at -16^0 C preceding chemical analysis. Milk from each animal has sampled 50 ml daily for N on fresh milk analysis and for drying in a forced draught oven at 49^0. The dried samples were ground using a porcelain

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pestle and mortar and stored for later chemical analyses.

Chemical and Statistical Analyses

According to standard procedures, the content of DM, ash, and organic matter (OM) of feeds, feed refusals, milk, fecal, and urine samples were determined (Association of Official Analytica Chemists, 1999). The (Goering & van Soest, 1970) was used to analyze neutral detergent fiber (NDF), while the acid detergent fiber (ADF) was analyzed by using a Fibretec System M1021 Hot Extractor (manufactured by Tecator AB, Höganäs, Sweden). Hemicellulose contents were calculated as ADF minus NDF. The N content was analyzed using an automatic FP-2000 nitrogen analyzer (LECO Corporation, Michigan, USA). Crude protein (CP) contents for diet, refusal, and urine samples were calculated as N x 6.25, while milk protein was calculated as N X 6.28. Gross energy (GE) contents were determined with a Parr Oxygen Bomb Calorimeter (Parr Instrument Company, USA), using benzoic acid as standard and correcting for total acid production by titration with 0.0709 N sodium carbonate solution.

Data from the sixth week of each period were analyzed statistically using the General Linear Model (GLM) procedure of SAS® (Der & Everitt, 2001) to determine dietary treatment effects. The statistical model included the goat, period, and treatment as independent variables when the dietary treatment effect was significant ($p<0.05$), and the least significant difference (LSD) test was run for means separation.

RESULT AND DISCUSSION

Feed, Nutrient Intakes, and Digestibility

Although the hay and concentrate were offered on a 50%: 50% DM basis, the goats consumed more concentrate, except in the BSBM treatment. Thus, the hay and concentrate intake proportions were not precisely as prescribed, but the treatments' difference was not statistically significant. The concentrate intake by goats fed BCSM was 6.3, 19.8, and 17.8% higher than those fed BM, BSBM, and BU, respectively. This increased N intake (NI). However, the treatments' digestible N intakes (DNI) were not significantly different (Table 4.1).

Even though concentrate intakes varied because of diet selection by goats, there was no difference among the treatments for DMI, OMI, and DOMI. However, overall, the goats on fed the BCSM treatment tended to have higher nutrient intakes than the other dietary N treatments. The fiber components (NDF and ADF) of goats when fed the BCSM treatment were significantly higher than when the goats were fed the BU ration, but the intakes were not significantly different from BM and BSBM treatments.

The digestibility coefficients of DM, OM, GE, NDF, and ADF were not affected by the source of dietary N (Table 4.1). However, the digestibility coefficient for N and hemicellulose was significantly different among treatments ($P<0.05$). Adding dietary N sources to concentrates increased dietary N apparent digestibility. The N digestibility for BU was 18.0, 8.9, and 11.3% higher than BM, BSBM, and BCSM, respectively. Goats on the BCSM treatment showed a significantly lower hemicellulose digestibility than goats on the BSBM and BU treatments. However, no significant differences were observed between the BSBM and BCSM treatments.

Although the concentrates tested in the present study were formulated to be isonitrogenous, nominally 2.7 % N for the added N source treatments and 1.7% N for the negative control barley only supplement, the actual N content of total intake (hay plus concentrate) of goats on the BM; BSBM; BCSM and BU treatments was 1.76; 2.22; 2.24; 2.26 % of DM respectively. This discrepancy arose because of a slight change in the proportion of hay and concentrated consumed. While 50:50 was offered to the goats, 47:53; 51:49; 46:54; 46:54 were actually consumed for the BM; BSBM, BCSM, and BU treatment. The goats selected the proportion of hay and concentrated to meet their apparent nutrient requirements. The 2.26 % dietary N content in total intake for the BSBM, BCSM, and BU treatments in the present experiment were in agreement with the optimum level of N intake, as suggested by Badamana and Sutton (1992). However, these treatments resulted in similar milk N, milk yield, and body weight changes compared to the BM negative control treatment, with only 1.7 % N in the concentrate and 1.76 % N in the total diet. Goats excreted more N via urine when higher N diets were offered. (Jardstedt et al., 2017) also found that increasing dietary N resulted in an increase in fecal and urinary N output. Similarly, (Schuba et al., 2017) showed that fecal N changed slightly with an increasing N intake, but urinary N increased markedly.

Table 2. Feed, nutrient intakes, and nutrient digestibility by dairy goats fed different N supplements.

	Treatments				
	BM	BSBM	BCSM	BU	SEM
Feed and nutrient intake					
Hay intake (g DM/ day)	878.3	930.3	917.5	762.8	52.30
Concentrate intake (g DM/ day)	996.0	883.8	1059.0	898.8	100.7
The ratio of hay : concentrate consumed	0.88	1.17	0.86	0.91	0.16
DMI (g/ day)	1862.0	1811.5	1952	1662.7	114.72
OMI (g/ day)	1728.1	1669.0	1799.5	1542.9	109.77
DOMI (g/ day)	1231.1	1170.6	1268.3	1119.8	96.83
DNI (g/ day)	19.6	26.0	28.0	26.7	2.44
NDF intake (g/ day)	705.3^{ab}	733.6^{ab}	989.1^{b}	639.3^{a}	99.44
ADF intake (g/ day)	304.0^{ab}	328.0^{ab}	356.0^{b}	254.2^{a}	21.48
Hemicellulose intake (g/ day)	403.1	414.9	435.2	366.5	21.93
Digestibility coefficients (%)					
Dry matter (DM)	69.2	68.1	67.8	70.7	1.16
Organic matter (OM)	70.9	69.9	69.6	72.2	1.23
Energy	67.5	68.7	68.9	69.4	0.46
Nitrogen (N)	60.0^{a}	65.0^{b}	63.6^{b}	70.8^{c}	1.21
Neutral detergent fiber (NDF)	48.0	51.2	55.4	51.5	4.7
Acid Detergent fibre (ADF)	37.3	44.7	41.6	33.0	5.46
Hemicellulose	56.0^{b}	57.7^{b}	51.9^{a}	57.8^{b}	1.47

All means within the same row with different superscripts are different (P<0.01).
BM = barley meal, BSBM= barley meal plus soybean meal, BCSM= barley meal plus cottonseed meal, BU= barley meal plus urea, SEM = standard error of the means.

This may indicate that goats offered low N diets might have higher efficiency of urea recycling. Further direct studies using different rations need to be developed to establish the utilization of recycled urea, particularly in the goats.

Dietary energy plays an essential role in optimizing the utilization of recycled urea. When sufficient dietary energy was available for ruminal microbial activities, the source of N did not affect N balance and microbial N synthesis (A. Rai Somaning Asih & Young, 2012).

In terms of digestibility coefficient, the present study showed that only the N digestibility could be improved significantly by adding dietary nitrogen sources (Table 2). There are no different effects on N balance, urinary N output, metabolic fecal N, and the highest coefficient of digestibility in goats fed on concentrate made of barley meal plus urea (BU) compared to other N source treatments. This indicated urea was a promising N source for milking goats, particularly in developing countries. The highest digestibility coefficient for the urea

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treatment (BU) is found because urea is completely soluble in the rumen and available to be utilized efficiently. Thus, N apparent digestibility increased as N concentration is increased since metabolic fecal N remained constant (Table 2). However, as the source of N for microbial synthesis in the rumen, farmers should not include the high amount of urea in the goat diet. Excessive urease activity in the rumen may lead to urea/ammonia toxicity (Patra & Aschenbach, 2018).

Production Responses and Dietary N Utilisation

The effects of feeding different N supplements on milk production and N utilization are presented in Table 3. Adding a dietary N source to the total diet raised the N content of the supplement from 1.8 % N up to 2.26 % (11.25 to 14.13 % protein), but did not affect milk production or milk N content, nor was there any difference among the dietary N sources in the supplement. Although body weight changes were not significantly affected by the treatments, the bodyweight changes of goats fed (BSBM) tended to be higher than goats offered other concentrate supplements.

Daily fecal N output of goats fed BCSM was higher than goats fed BM, BSBM, and BU concentrates. The later treatments (BM, BSBM, and BU) were not statistically different in N utilization. Results presented in this study indicate that significant amounts of excess N were excreted through the urine. However, differences in urinary N were not found among the dietary treatment with added N. There was a significant positive correlation (r = 0.74 or R^2 = 0.55) between N intake (NI) and N in the urine.

The NI of cottonseed treatment was the highest, and its total N output was also the highest. Finally, similar N retention and positive N balances were observed in all treatments (Table 3). Thus, N balance was not affected by dietary N treatment in the present study**.**

Table 3. Production responses and nitrogen utilization by goats fed different dietary N supplements (week 6 of each period).

	Treatments				
	BM	BSBM	BCSM	BU	SEM
Production responses					
Milk production (g/ day)	1466	1421	1541	1311	120.1
N content of milk (%)	0.50	0.53	0.53	0.52	0.009
The efficiency of milk production (g milk/ g DMI)	0.78	0.81	0.80	0.79	0.04
Initial BW (kg)	71.6	72.7	72.2	70.3	0.71
BW gain (g/ day)[#]	+9	+109	+14	+64	25.65
Nitrogen utilization					
N I (g/ day)	32.8 [a]	40.3 [ab]	43.8 [b]	37.5 [a]	2.91
Milk N (g/ day)	7.27	7.35	8.03	6.75	0.49
Fecal N (g/ day)	13.2 [a]	13.3[a]	16.3 [b]	10.8 [a]	0.82
Urinary N (g/ day)	8.7 [a]	16.0 [b]	15.6 [b]	16.0 [b]	1.70
Total N output (g/ day)	29.1 [a]	36.6 [ab]	39.9 [b]	34.2 [a]	2.76
N balance (g/ day)	+3.7	+3.7	+3.9	+3.3	0.15

[#] Average body weight changes for six weeks of each period.

Means within the same row with different superscripts are different ($p<0.01$).

DMI= Dry Matter Intake, NI=Nitrogen Intake, BM= barley meal, BSBM= barley meal plus soybean meal, BCSM= barley meal plus cottonseed meal, BU= barley meal plus urea, SEM = standard error mean.

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The lack of significant responses in intake of dry matter, organic matter, and digestible organic matter across the treatments (Table 2 and Table 3) may be more related to the insignificant difference in the goats' initial body weight used in the experiment. Average daily body weight gains (9; 109; 14, and 64 g/day for BM; BSBM; BCSM, and BU, respectively) differed amongst the treatments. These bodyweight changes tended to be reduced when more milk was produced. The lack of significant differences in milk yield, N contents of milk, and feed efficiency (milk/DMI) amongst treatments were probably due to similar digestible organic matter intake (DOMI) and digestible dietary N intake (DNI) amongst treatments (Table 2).

The results of the present experiment are in line with those reported by (BRUN-BELLUT et al., 1985), who found that increasing the level of N content of diets from 1.9 to 2.4 % DM offered to milking Alpine goats did not significantly increase milk yield, N content of milk or feed efficiency. Similarly (Ramos Morales et al., 2010; Schuba et al., 2017), under similar N and energy intakes, fecal and urinary excretion of N and the quantities in milk did not vary significantly. The utilization of dietary nitrogen might be highly influenced by the availability of digestible energy in the diets. As in the present study, (Badamana et al., 1990) were also unsuccessful in increasing the N content of Saanen goats' milk by increasing the N levels of concentrate supplement, but milk yield and hay intake were increased. The stage of lactation may also influence the response of increasing N in concentrates on milk yield. The goats used by (Badamana et al., 1990) were in early lactation (3 weeks after kidding) compared to the present study, where the goats were in late lactation (after 2.0 to 2.5 months after kidding). Further work by (Badamana & Sutton, 1992) recorded that hay intake and milk yield were not increased by increasing the level of N content of the concentrate up to 4.1% (2.72 % N in total diet). They concluded that the optimum N content of a concentrate supplement for dairy goats was 2.9 % or 2.24 % N per kg DM total diets. The present study found that feeding concentrate supplement with 1.76 % N (BM) gave a similar response in milk yield, milk efficiency, and milk N content as a supplement with 2.26% N per kg DM.

Regarding the utilization of N sources by milking dairy goats, the findings of the present studies contradict those of (Lu et al., 1990), who evaluated the utilization of soybean and hydrolyzed feather meals for milking Alpine goats. By offering isonitrogenous and isoenergetic diets (16 % CP and 2.4 Mcal ME/kg DM) to their goats, Lu and co-workers found that milk protein content increased with soybean meal supplementation. Several workers (Greyling et al., 2004);(da Costa et al., 2014) had found that the level of protein in milk from goats differed between breeds, even though they were given similar diets. The above observation by (Lu et al., 1990) may be a breed-specific response or probably due to amino acid compositional differences between feather meal and soybean meal, and these need further investigation.

The urinary N excretion of the BU treatment was significantly higher than the BM treatment but still comparable to other N sources (BSBM and BCSM). However, total milk N and N balance across treatments were not significantly different. The present study indicates that urea can maintain similar milk yield and milk protein levels, and milk efficiency in goats relative to soybean and cottonseed meals, provided the diet's level of readily available energy is similar.

The goats were in positive N balance across all treatments, and no significant differences were observed in retained N in the present study (Table 2). These results were not in line with the results of our previous studies on growing goats (A. Rai Somaning Asih & Young, 2012; A. R.S. Asih et al., 2011), where the negative control (BM) treatment produced lower N retention.

The different patterns presumably cause this difference in N intake or DNI in each experiment across the treatments. In the growing goat experiment, NI of BM was significantly lower. In contrast, in the milking goat experiment, DNI of the negative control treatment (BM) was not significantly different compared to N source treatments. In addition, milking goats fed the BM negative control diet compensated in responding to the low N diet by reducing their urinary N excretion (Table 2).

The goats seem relatively efficient in utilizing N when fed low N in high-energy diets. The goats fed the negative control treatment (BM) in the present study seemed to be more efficient in N utilization than goats fed a diet with higher N content. Amongst the N added treatments, the goats fed the urea treatment (BU) showed similar responses in N utilization compared to the goats fed soybean meal or cottonseed meal. The amount of fecal N excreted by goats fed the BU treatment was about_20% less than those fed the BM and the BSBM and 34% less than those fed the BCSM diet. These responses indicated that the goats underwent metabolic adjustment to each introduced diet before reaching the actual response. The changed responses seemed not only the result of intake of dietary treatment change but also seemed to be a carry-over effect. These results indicated that when markedly different types of diet are applied to goats, the length of adjustment time and variables observed should be considered.

Milking goats could maintain milk production when the goats were given test diets containing different types of N sources, even though the N balances were negative and fluctuated during the adjustment periods (before the sixth week of each period) depending on the type of N tested. These findings support the theory (Barnes & Brown, 1990) that milking goats can maintain their milk production for as long as a month with negative N balances. Therefore, they suggested that studies involving several types of dietary N or concentrations in milking goats that employ a Latin square and other cross-over designs need to incorporate adaptation periods of at least six weeks for valid observation of the response.

CONCLUSIONS

The present study indicated that milking goats produce 1.3 to 1.5 liters of milk per day. Offered a concentrate containing 1.7 % N in a high-energy diet can maintain similar milk protein and nitrogen balance as goats offered 2.2 % dietary N in a similar high energy concentrate diet. The excess N ingested was excreted in the urine. Total nutrient intakes, nutrient digestion, milk-feed efficiency, and milk production in late lactating Saanen goats were not affected by the three different dietary nitrogen sources used in the present study. Digestible organic matter intakes and the levels of available dietary energy seem to be more critical for milk production than dietary N intake. The results indicate that urea in a supplement can maintain a similar level of milk yield, milk protein, and milk efficiency in goats, as can the feeding of more expensive soybean and cottonseed meals, provided there is sufficient readily available dietary energy.

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