The Prediction of Ruminal Ammonia Nitrogen Concentration from some Dietary Components in Sheep

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ABSREACT

The relationship between ruminal ammonia-nitrogen concentration (NH_3-N) and the dietary contents of crude protein (CP), digestible crude protein (DCP) and total digestible nutrients (TDN) were estimated using 64 different diets that varied in CP (ranging from 8 to 18%), in DCP (ranging from 5 to 14%) and in TDN (ranging from 49 to 79%). Dietary CP, DCP and TDN were suggested as basis for the criteria relating to the ruminal ammonia nitrogen concentration in sheep. The relationships between CP (X_1) and/or DCP (X_2) and NH_3-N (Y) as linear and quadratic equations were not significant. The inclusion of TDN as X_3 resulted in higher multiple correlation coefficient either with CP or DCP; the higher value was obtained with DCP and TDN. Mean ammonia-nitrogen concentration in the rumen reached the level of 5.5mg/100ml rumen liquor (RL) at approximately 10% dietary digestible protein as calculated from the prediction equation, above this level, ammonia increased rapidly with increasing digestible protein in the diet.

Key Words: Dietary CP, DCP, TDN, ruminal ammonia-N concentration, prediction equations, sheep.

INTRODUCTION

The regression of ruminal ammonia nitrogen concentration on one or more of the diet composition has been estimated by many investigators (Sater and Slyter, 1974; Sater and Roffler, 1975; Offer and Percival, 1998; Brown *et al.*, 2000 and 2001). Data of 35 different diets that varied in crude protein (from 8 to 24%) and in total digestible nutrients (from 53 to 85%) were analyzed (Sater and Roffler, 1975) and the mean ruminal nitrogen concentration in cattle was reported to vary from 0.8 to 56.1 mg/100ml RL with increasing dietary protein levels. They concluded that mean ruminal ammonia concentration could be predicted using the following equation:

$$NH_3\text{-}N = 38.73 - 3.04(X_1) + 0.171(X_1)^2 - 0.49(X_2) + 0.0024(X_2)^2$$

where, X_1 and X_2 represents CP and TDN, respectively; $R^2 = 0.92$.

When they used CP (X) as the only predictor for NH_3-N concentration in cattle, the prediction equation was:

$$NH_3\text{-}N = 10.57 - 2.5(X) + 0.159\,(X)^2;\ R^2 = 0.88$$

Applying the equations of Sater and Roffler (1975) to predict the ruminal ammonia concentration in sheep is not acceptable because of the variation in rumen fermentation patterns between large (cattle) and small (sheep) animals (Naga, 1992). This paper presents and discusses a mathematical approach for relating some of the dietary composition to predict ruminal ammonia nitrogen concentration in sheep.

COMPILATION AND DATA ANALYSIS:

Ruminal ammonia concentration (NH_3-N, mg/100ml RL) and percentage of some dietary components (CP, DCP and TDN) were compiled from 64 digestibility and rumen fermentation studies which were carried out at the Department of Animal Production of Alexandria University. Diets varied in crude protein (ranging from 8 to 18%), in digestible crude protein (ranging from 5 to 14%) and in total digestible nutrients (ranging from 49 to 79%).

The regression lines of ruminal ammonia nitrogen concentrations (NH_3-N as Y) and dietary composition (CP, DCP and TDN as X_i) of the compiled data (Fig. 1 and 2) shows two different trends corresponding to CP% on one hand and both DCP and TDN% on the other. The relationships between NH_3-N concentration and the dietary components were estimated by multiple linear regressions using the statistical program of SAS (2000). The correlation coefficients between variables (X_1, X_2 and X_3) and (Y) were always above 0.70. A regression equation for each variable was therefore formulated, and then the regression equations that used to predict ruminal NH_3-N (Y) concentration from CP (X_1), DCP (X_2) and TDN (X_3) were presented:

$$Y = -1.30 - 2.0(X_1) + 0.8(X_1)^2 + 0.64(X_3) - 0.003(X_3)^2$$

$$Y = 17.25 - 4.23(X_2) + 0.25\,(X_2)^2 + 0.15(X_3) - 0.001(X_3)^2$$

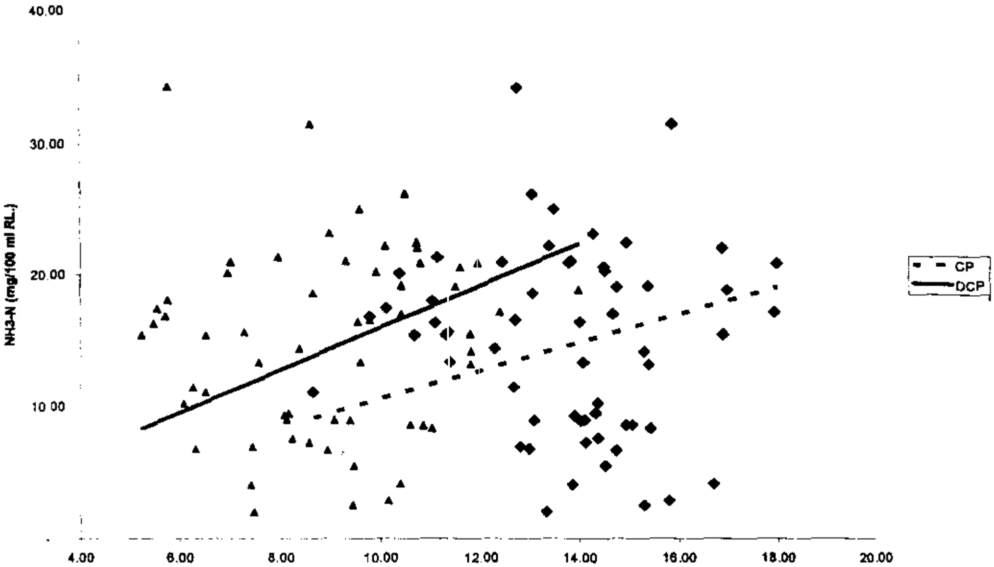

Fig (1): The regression lines of NH_3-N on CP and DCP percentage

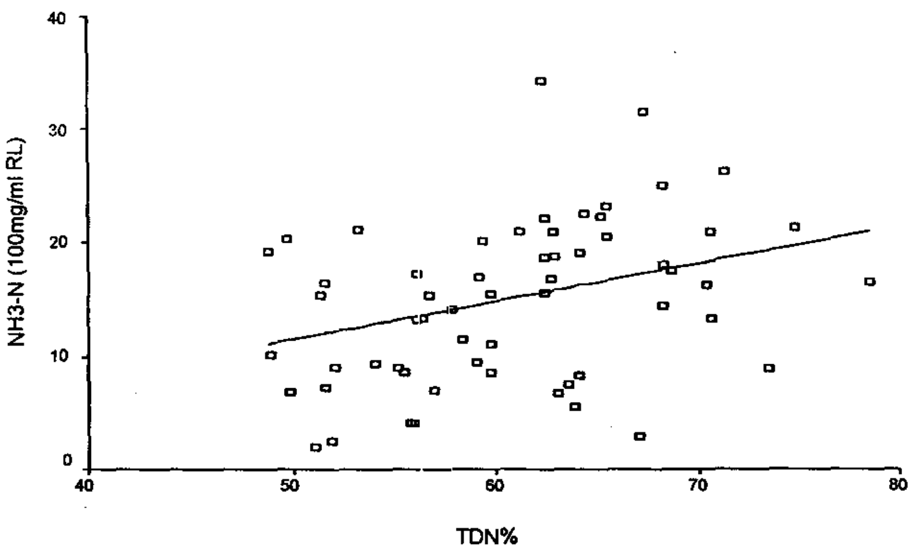

Fig (2): The regression line of NH_3-N on TDN percentage

RESULTS AND DISCUSSION:

Table (1) shows the regression equations for the prediction of NH_3-N in the rumen of sheep. The last two equations gave a reasonable (R^2) coefficient of determination (0.71 and 0.79), respectively.

Table 1: Linear and quadratic regression equations between diet composition data (CP, DP and TDN)* and NH_3-N* concentration in sheep (n=64)

Prediction Equations	R^2
$Y= 17.95 - 0.21X_1$	
$Y= 11.94 + 0.34X_2$	
$Y=-4.92 + 0.33X_3$	
$Y=40.03 - 3.55X_1 + 0.12X_1^2$	
$Y=33.21 - 4.67X_2 + 0.28X_2^2$	
$Y=-21.71 + 0.89X_3 - 0.005X_3^2$	
$Y=-6.05 + 0.06X_1 + 0.33X_3$	
$Y=-7.57 + 0.31X_2 + 0.33X_3$	
$Y=21.48 - 1.38X_1 + 1.40X_2$	
$Y=- 1.30 - 2.0X_1 + 0.08X_1^2 + 0.64X_3 - 0.003X_3^2$	0.71**
$Y=17.25 - 4.23X_2 + 0.25X_2^2 + 0.15X_3 - 0.001X_3^2$	0.79**

*CP, dietary crude protein; DCP, digestible crude protein; TDN, total digestible nutrients; NH_3-N, ruminal ammonia nitrogen concentration.
** P<0.01

Using these two equations, the ruminal levels of ammonia were calculated for diets that were varying in CP, DCP and TDN contents, and then data were presented in Tables (2 and 3). The present results show that low levels of ruminal ammonia nitrogen were observed with low CP, DCP and TDN-diets comparing with high energy ones with increasing protein. Ruminal ammonia nitrogen concentration was found to be highly affected by diet composition (Hristov *et al.*, 2004). Regression equation including TDN and CP for the prediction of ammonia concentration in the rumen of cattle (Sater and Roffler, 1975) is completely different than that of sheep obtained in the present study. This may be due to the differences in rumen activity patterns between large (cattle) and small (sheep) ruminants (Naga, 1992).

Increasing dietary protein concentration usually results in increased ammonia-N concentrations in the rumen (Table 2). Similar results were presented in many other reports (Armentano *et al.*, 1993; Castillo *et al*, 2001; Davidson *et al.*, 2003; Olmos Colmenro and Broderick, 2003).

Diets with elevated CP concentration usually have greater apparent N-digestibility (Broderick, 2003); the present results confirmed these findings (Tables 2 and 3).

Results in (Table 2) suggest that rumen ammonia-N concentration ranged between 12.51 and 19.11 mg/100ml RL at 14% dietary crude protein and between 55 and 85% of dietary TDN.

Table 2: Influence of diet composition (percentages of CP and TDN) on mean ruminal ammonia-N concentration* (mg/100ml RL) in sheep

Dietary CP%	TDN% On DM basis						
On DM basis	55	60	65	70	75	80	85
8	16.54	15.42	16.75	17.92	18.95	19.82	20.55
9	13.31	14.78	16.11	17.82	18.31	19.18	19.91
10	12.83	14.30	15.63	16.80	17.83	18.70	19.43
11	12.51	13.98	15.31	16.48	17.71	18.38	19.11
12	12.35	13.82	15.15	16.32	17.35	18.22	18.95
13	12.35	13.82	15.25	16.42	17.45	18.32	19.05
14	12.51	13.98	15.13	16.48	17.51	18.38	19.11
15	12.83	14.30	15.63	16.80	17.83	18.70	19.43
16	13.31	14.78	16.11	17.28	13.31	19.18	19.91
17	13.59	15.42	16.75	17.92	13.59	19.81	20.55
18	14.75	16.22	17.55	18.72	14.75	20.62	21.35
19	15.71	17.18	18.61	19.78	15.71	21.62	22.41
20	16.83	18.30	19.63	20.80	16.83	22.70	23.43

*Calculated from the prediction equation in Table (1) from CP and TDN

Table 3: Influence of dietary composition (percentages of DCP and TDN) on mean ruminal ammonia-N concentration* (mg/100 ml RL) in sheep

DCP% On DM basis	TDN% On DM basis						
	55	60	65	70	75	80	85
5	7.58	7.75	7.88	7.95	7.98	7.95	7.88
6	6.10	6.27	6.40	6.47	6.50	6.74	6.40
7	5.34	5.51	5.64	5.71	5.74	5.71	5.64
8	4.64	4.81	4.94	5.01	5.04	5.01	4.94
9	4.66	4.83	4.96	5.03	5.06	5.03	4.96
10	5.18	4.35	5.48	5.55	5.58	5.55	5.49
11	6.20	6.37	6.05	6.57	6.60	6.57	6.50
12	7.72	7.89	8.02	8.09	8.12	8.09	8.02
13	9.74	9.91	10.04	10.11	10.14	10.11	10.04
14	12.26	12.43	12.56	12.63	12.66	12.63	12.56

*Calculated from the prediction equation in Table (1) from DCP and TDN.

Mehrez *et al.* (1977) found an increase in the rate of rumen fermentation and substrate degradation when rumen ammonia-N concentration reached 21mg/100ml RL. The concentration of ammonia-N in the rumen is a function of both rate of ruminal-N degradation and concentration of rumen degradable protein above microbial needs and the amount of dietary energy available to the ruminal microorganisms. (Tamminga *et al.*, 1994; NRC, 2001). On the other hand, the rate of digestion and feed intake are reduced with low ruminal ammonia-N concentration due to starvation of ruminal bacteria for ammonia (Sater and Sylter, 1974). Mean ammonia-N concentration in the rumen reached 5.5mg/100ml RL at approximately 10% digestible protein (Table 3); above this level, ammonia-N increased rapidly with increasing dietary crude and digestible protein (Tables 2 and 3). Results of Sater and Roffler (1975) stated that 5mg of rumen ammonia-N/100ml RL is required for minimum rumen microbial growth.

The success of any system for the prediction of ruminal fermentation patterns depends on the extent that this system can counteract the sources of variability. Most digestibility and fermentation trials are conducted using a small number of animals (2-4), which is less than the ideal number required to overcome the individual variation between animals. This was clear from the work of Bredon *et al.* (1961). On the other hand, the regression equations based on diet composition to predict the rumen fermentation patterns give lower values of R^2 as compared to other systems of prediction (Brown *et al.*, 2000 and 2001).

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الملخص العربي

التنبؤ بتركيز نيتروجين الأمونيا في كرش الأغنام باستخدام بعض مكونات العليقة

على محمد علام

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أجريت هذه الدراسة لمعرفة أمكانية تقدير نيتروجين الأمونيا فى سائل الكرش للأغنـام عـن طريق بعض مكونات الغذاء (بروتين خام – بروتين مهضوم– مواد غذائية مهضومة). تم تجميع النتائج الخاصة بالمتغيرات تحت الدراسة (بروتين خام – بروتين مهضوم– مواد غذائية مهضومة – تركيـز الأمونيا مجم/١٠٠مل) من الدراسات التي تم أجراؤها فى قسم الإنتاج الحيواني – كلية الزراعة – جامعة الاسكندرية وذلك لعدد ٦٤ عليقه. وقد كانت العلائق تحتوى على (٨–١٨%) بروتين خـام , (٥–١٤%) بروتين مهضوم , (٤٩–٧٩%) من المركبات الغذائية الكلية المهضومة. وقد أمكن الحـصول مـن هـذه النتائج الخام على علاقتين تشابهتا فى علاقة تركيز الأمونيا وكل من البـروتين المهـضوم و المركبـات الغذائية الكلية المهضومة – وكانت العلاقة مختلفة مع البروتين الخام. ثم تم اسـتنباط معـادلتين لتقـدير العلاقة بين تركيز الأمونيا فى الكرش وكل من البروتين الخام والبروتين المهضوم مع المركبات الغذائيـة الكلية المهضومة. وقد تم حساب معدل أنتاج الأمونيا نظريا بناء على هذه المعادلات.

وقد أوضحت نتائج الدراسة ما يلي:

١- تركيز نيتروجين الأمونيا فى الكرش يرتبط ارتباطا وثيقا بمكونات العليقة.

٢- استخدام المعادلة التي تجمع بين كل من البـروتين المهـضوم و المركبـات الغذائيـة الكليـة المهضومة كانت أدق من تلك المحسوبة على أساس البروتين الخام و المركبات الغذائية الكليـة المهضومة.

٣- أن الدراسة يمكن أن تعكس الفروق فى نشاط الكرش بين كل من الحيوانات الصغيرة (الأغنام) والحيوانات الكبيرة (الماشية).

٤- أوضحت الدراسة زيادة تركيز الأمونيا فى الكرش بزيادة مكونات العليقة من كل من البـروتين الخام و المهضوم.