Influence of different combinations of urea and low ruminal degradable protein sources on performance of high-producing dairy cows

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Three complete diets with crude protein 16% and energy value 9,4 MJ ME/kg DM were formulated using different combinations of high and low-degradable protein sources. Diet A was formulated with only natural protein sources (55% UDP), diet A1 contained 1,6% urea in the total diet (41% UDP) and diet A2 contained 1,0% urea in the total diet (47% UDP). The experimental diets were allocated to 21 cows per treatment from week 4 through 33 of lactation. From week 4 through 17 of lactation the average milk production was 28,5; 27,8 and 28,1 kg/d for diets A, A1 and A2 respectively. During the total experimental period from week 4 through 33 the average milk production was 23,8; 23,8 and 22,6 kg/d for diets A, A1 and A2 respectively. A level of up to 1,6% urea (total diet) would cause no fall in milk production of high-producing dairy cows when included into 16% crude protein complete diets with an abundance (when compared to the 1980 ARC specifications) of UDP supplied. There was a tendency for the difference in milk production between treatments to increase as the production potential of the cows increased. Therefore only up to 1% urea in the total diet, supplemented with high-quality, low-degradable protein sources providing 47% UDP is advocated for exceptionally high producers when compared to diets providing 41 and 55% UDP. This study has shown that urea can be utilized effectively and economically by high-producing cattle during early lactation when the crude protein level is 16% and UDP are in excess.
S. Afr. J. Anim. Sci. 1986, 16: 169 – 176

Drie volledige diëte met 16% ruproteïen en energiewaarde van 9,4 MJ ME/kg DM is geformuleer deur gebruik te maak van verskillende kombinasies van hoog- en laagdegradeerbare proteïenbronne. Dieet A is geformuleer met slegs natuurlike proteïenbronne (55% UDP), dieet A1 het 1,6% ureum in die totale dieet bevat (41% UDP) en dieet A2 het 1,0% ureum in die totale dieet bevat (47% UDP). Hierdie diëte is toegeken aan 21 koeie per behandeling vanaf week 4 – 33 van laktasie. Gedurende week 4 – 17 was die gemiddelde melkproduksie gelewer deur diëte A, A1 en A2 28,5; 27,8 en 28,1 kg/d. Indien die volle eksperimentele periode vanaf week 4 tot 33 van laktasie in ag geneem word was die gemiddelde melkproduksie tydens hierdie periode 23,8; 23,8 en 22,6 kg/d vir diëte A, A1 en A2 respektiewelik. 'n Insluitingspeil van tot 1,6% ureum (totale dieet) sal nie 'n daling in melkproduksie veroorsaak wanneer volledige diëte met 'n 16% ruproteïenpeil en 'n oormaat UDP (wanneer vergelyk word met die ARC 1980 aanbevelings) voorsien word nie. Die verskil in melkproduksie tussen diëte het toegeneem met toenemende produksiepotensiaal. Vir uitsonderlike hoë produseerders word derhalwe tot 1% ureum in die totale dieet, gesupplementeer met hoë kwaliteit laagdegradeerbare proteïenbronne aanbeveel waar 47% UDP verskaf word, indien vergelyk word met diëte wat 41 en 55% UDP verskaf. Hierdie studie het aangedui dat ureum effektief en ekonomies aangewend kan word in volledige diëte vir hoogproduserende melkkoeie tydens vroeë laktasie wanneer die ruproteïen 16% is en 'n oormaat UDP verskaf word.
S.-Afr. Tydskr. Veek. 1986, 16: 169 – 176

Keywords: Urea, low degradable protein sources, high milk producers, complete diets, dacron bag technique.
Extract from M.Sc (Agric) thesis submitted by the senior author to the University of Pretoria.

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Received 20 September 1985

Introduction

In the Republic of South Africa the estimated protein deficit by the year 2000 is 480 000 tons (Cloete, 1984). Therefore, it is of great importance to investigate those conditions which will maximize the use of urea in dairy cattle rations (Cunha, 1984).

Dairymen are hesitant to use even recommended proportions of urea because of practical problems which include inconvenience of feeding, palatability, variable responses and inconclusive evidence from research regarding long-term effects on reproduction and general health (Erb, Brown, Callahan, Moeller, Hill & Cunningham, 1975; Huber, 1984). This, together with the sometimes biased adverse publicity, is a reason why the usage of urea in Europe is only about one-tenth of its potential (Corse, 1981). However, the main reason is still the considerable controversy that has developed over whether or not to include urea in the diets of high producing dairy cattle during early lactation (Huber & Kung, 1981; Jiminez, 1983).

When the ammonia-nitrogen level in the rumen fluid exceeds 5 – 7 mg/100 ml there may be relatively little or no increase in the amount utilized for synthesis of microbial protein (Waldo, 1968; Satter & Roffler, 1975). At around 7 mg/100 ml rumen fluid the quantity of ammonia-nitrogen absorbed about equals the urea coming into the rumen from saliva and through the rumen wall (Waldo, 1968). Based on this type of information it was suggested that supplemental NPN may have little or no value in typical dairy cattle diets containing more than 12 – 13% crude protein (CP) on a dry matter (DM) basis (Burroughs, Nelson & Mertens, 1975; Satter & Roffler, 1975). Dairy cows in early lactation should be supplemented with only natural protein to 16% CP and supplemental NPN (urea) would be satisfactory for the remainder of the lactation for diets of 12 – 13% CP fed from 14 weeks post-partum (Bergen, 1979; Clark & Davis, 1980; Satter & Roffler, 1981). This limit has been adopted by a large part of the feed industry, but is based on very little solid evidence (Huber, 1984).

Chalupa (1975) and Bull, Poos & Bull (1977) suggested that it is feasible to use NPN to supply the ammonia needs of the rumen microbes and to supplement the diet with natural proteins or amino acids that are not degraded to ammonia in the rumen. Using this approach, it should be possible to utilize considerable amounts of urea efficiently even in high protein diets when such levels are needed to meet protein requirements (Miller, 1979). There are several studies suggesting that urea feeding is compatible with high milk yields during early lactation (Holter, Colovos & Urban, 1968; Kwan, Coppock, Lake, Fettman, Chase & McDowell, 1977; Foldager & Huber, 1979; Casper & Schingoethe, 1984; Oldham, Napper, Smith & Fulford, 1985).

Studies have shown that NPN can be incorporated effectively into diets of up to 17% CP for dairy cattle if a large proportion of the supplemental protein has limited degradability in the rumen (Lindquist, Johnson & Otterby, 1981; Kung & Huber, 1983; Higginbotham, Johnson, Adres & Huber, 1984). The basis of the ARC system (ARC, 1980; 1984) helps to explain these results and suggests that diets providing combinations of NPN and rumen undegradable protein may best support protein needs for high milk production as well as yielding greatest profits.

Studies of milk production where diets have been formulated on estimated rumen degradability have been few (Erdman & Vandersall, 1983). Feeds of low rumen degradability were more productive than controls in some studies (Forster, Grieve, Buchanan-Smith & Macleod, 1983; Sahlu, Schingoethe & Clark, 1984) but not in others (Throckmorton & Leng, 1982; Craig & Broderick, 1983; Erdman & Vandersall, 1983).

The aim of the experiment reported here was to investigate the effects of replacing natural protein sources of low degradability with urea-N in the diet of high producing cows from week 4 through 33 of lactation, as well as the feasibility of formulating dairy cattle diets according to percentage RDP (rumen degradable protein) and UDP (undegraded protein) in the total diet. A nylon bag study was used to test protein disappearance of the dietary ingredients.

Experimental procedures

Degradability experiment

Because a concurrent milk production trial was based on selection of feedstuffs for rumen degradability, validation of rumen protein degradability of the specific feedstuffs was needed. During the initial planning of the experiment, degradability values obtained with sheep (Cronjé, 1983) were used, and these proved to be of the same order as the values obtained in this study. A method of combining degradation rate with the fractional outflow rate of protein supplements from the rumen was used (Miller, 1980; Mathers & Miller, 1981), therefore a fractional outflow rate was calculated (Erasmus & Grové, 1986).

Four lactating Friesian/Holstein cows fitted with 100 mm diameter rumen cannulas were used. Their average live mass was 550 kg (± 22,5 kg) and the average production during the previous lactation was 5 000 kg (± 461 kg). They were fed on an *ad lib* basis one of the experimental diets (diet A2, Table 1) used in the milk production trial for 3 weeks before the start of the collection period.

Bags measuring 160 mm × 90 mm were made from polyester material (pore size 53 μm). Preparation of the bags is described by Ørskov, Hovell & Mould (1980) and Cronjé (1983). A 5 g (air-dry) feed sample, which had been ground in a laboratory mill to pass through a 5 mm screen, was weighed into each bag. The feedstuffs tested were fishmeal, cottonseed cake meal, maize meal and *Eragrostis curvula* hay. Seven bags per feedstuff were prepared and tested in the rumen of each of the four cows and withdrawn after 1, 2, 4, 6, 8, 12 and 24 hours respectively. This procedure was repeated once, giving a total of eight observations for each variable studied. Only two feedstuffs were tested per cow at the same time, giving a maximum of 14 bags during initial incubation.

After removal from the rumen the bags were rinsed in water until the fluid squeezed from the bags was clear and then dried at 70°C for 24 h. Nitrogen content of dried samples was determined by the macro-Kjeldahl method (AOAC, 1975).

The results were computed according to the method described by Miller (1980). Effective degradation is calculated as follows:

$$\text{degradability} = a + (1 - a)\frac{kd}{kr + kd}$$

where a is the proportion of nitrogen disappearing at time = 0; kd is the rate constant for nitrogen disappearance; and kr is the fractional outflow rate of undegraded protein from the rumen. Fractional disappearance rates of nitrogen were obtained by plotting the negative natural logarithm of the proportion of nitrogen remaining in the bag versus time from 1 to 12 h. Depending on the dry matter intake of the cow at the time of the dacron bag study, different outflow rates were used as determined in the rate of passage study (Erasmus & Grové, 1986).

Milk production experiment

Sixty-three mature Friesland/Holstein cows (second or later lactation) producing at least 20 kg of milk after the third week post-partum were used in a 30-week lactation trial to investigate effects of replacing natural protein sources of low degradability with urea-N from week 4 through 33 of lactation. The cows were fed diet A (Table 1) from calving to 21 days post-partum. At 22 days cows were randomly allocated to one of three isocaloric and isonitrogenous diets, varying in amount of urea (Table 1). The second lactation cows were allocated separately, resulting in three groups consisting of 10 second-lactation and 11 third or later lactation cows.

The experimental diets comprised pelleted complete diets having a ratio of *Eragrostis curvula* hay to concentrate of 38:62. Cows were housed in a deep-litter system and fed at *ad libitum* intake using Calan electronic feeding gates. Milk yield was measured twice daily with 10- and 14 h milking intervals. Composite samples from morning and afternoon milk were analysed every second week for milk fat and protein by infrared analysis. Body mass of cows and dry matter intake was measured weekly.

Three lactating Friesland/Holstein cows were used to determine the digestibility of the experimental diets by means of 3 × 3 Latin square design. Three additional fistulated cows were used in a 3 × 3 Latin square experiment (three 4-week periods) to determine pH and NH_3-N of rumen fluid. Rumen fluid samples were obtained via the rumen fistula at 08h00, 10h00, 12h00, 14h00 and 16h00 for five consecutive days during the last week of each period. Rumen fluid was strained through four layers of cheesecloth and pH determined immediately by a glass electrode pH meter. A 100 ml sample of rumen fluid was acidified with 10 ml of 10% (v/v) H_2SO_4 and stored at 3°C for subsequent analysis of NH_3-N by means of the Auto Analyzer II method no 334/74A.

All data were subjected to analysis of variance. Significant differences were measured at 5% probability. In addition data from those cows producing ≥ 30 kg during week 4 of lactation ('high' producers, n = 10/treatment) and those producing ≥ 31 kg during week 3 of lactation ('exceptionally' high producers, n = 7/treatment) were analysed separately by the above method.

Results and Discussion

Degradability experiment

Taking into account the different feed intakes and corresponding outflow rates (Erasmus & Grové, 1986) the effective percentage protein degradability of the different feedstuffs was as follows: cottonseed cake meal (56%), *Eragrostis curvula* hay (32%), maize meal (58%) and fishmeal (32%). The percentage protein degradation of the feedstuffs is lower than the values reported by Cronjé (1983), although still of the same order. This was to be expected because of the higher outflow rate in cows than in sheep owing to the relatively higher intake of cows (Ha & Kennely, 1984).

The results of the present study emphasize the importance of correcting for rates of outflow from the rumen to determine the effective protein degradability, as the rate of outflow may have pronounced effects on the degradation of most protein supplements from the rumen. For example, Ørskov, Hughes-Jones & McDonald (1981) calculated that the effective degradability of soybean meal would be reduced from 0,89 at a fractional outflow rate of 0,01/h to 0,67 at a fractional outflow rate of 0,04/h.

Table 1 Formulation, composition, apparent digestibility coefficients and protein degradation of the experimental diets

	Diets		
	A (no urea)	A1 (1,6% urea)	A2 (1,0% urea)
Components			
Eragrostis curvula hay, %	38,0	38,0	38,0
Maize meal, %	41,0	46,4	43,0
Fish-meal, %	9,0	5,5	7,0
Cottonseed cake meal, %	9,0	5,5	8,0
Urea, %	–	1,6	1,0
Mineral and vitamin premix, %	3,0	3,0	3,0
Composition			
Dry matter, %	90,3	90,4	90,8
Crude protein, %	16,0	16,2	16,3
Digestible protein, %	11,4	11,6	11,6
Crude fibre, %	15,8	15,6	15,7
Metabolizable energy, MJ/kg DM	9,42	9,32	9,35
Apparent digestibility coefficients			
Dry matter, %	64,6	64,5	65,0
Energy, %	63,2	62,9	64,4
Crude protein, %	71,2	71,3	71,4
Effective degradability			
RDP, %	45	59	53
UDP, %	55	41	47

Milk production experiment

The composition of the experimental diets is given in Table 1. The CP content and estimated metabolizable energy (ME) values show no significant differences between the diets ($P > 0,05$). The mean apparent digestibility coefficients are also given in Table 1 and show no significant differences ($P > 0,05$). The percentage degradability was obtained using the data from the degradability trial.

No significant differences ($P > 0,05$) in body mass and DMI were found when data from all 21 cows per treatment (AC) were considered (Table 2). However the DMI of the 'high' producers (HP) and the 'exceptionally high' producers (EHP) receiving diet A1 was significantly lower (18,3 and 18,4 kg/d) as opposed to that of the cows receiving diet A (19,7 and 19,6 kg/d) and diet A2 (20,2 and 20,6 kg/d) during week 4 through 33 of lactation. This helps explain the lower average body mass for the HP and EHP cows receiving diet A1, although they started with a somewhat lower average mass.

The DMI of the AC-group and EHP-group is illustrated graphically in Figure 1. During week 18 – 33 the EHP cows receiving diet A1 had a lower DMI and produced more milk than the other two groups. During the later stages of lactation the crude protein content of the diet can be reduced from 16 to 12% of the total without lowering the milk production (Clark, 1981). It is therefore clear that an abundance of protein was supplied together with sufficient energy for the production levels achieved (NRC, 1978). An interaction between treatment and yield capacity here is unlikely and results obtained may be attributed to the use of few cows from

Table 2 Mean daily dry matter intake (DMI) and mean body mass from all cows (AC), high producers (HP) and exceptionally high producers (EHP) fed diets^{+} differing in level of urea and protein degradability

	AC group*					HP group**					EHP group***				
	Week					Week					Week				
Item	1 – 3	4 – 8	4 – 17	18 – 33	4 – 33	1 – 3	4 – 8	4 – 17	18 – 33	4 – 33	1 – 3	4 – 8	4 – 17	18 – 33	4 – 33
DMI (kg/d)															
Diet A	15,1	18,8	19,4	18,1	18,7	14,7	19,0^{a}	20,3^{ab}	19,1^{a}	19,7^{a}	16,3	20,1^{ab}	20,8	18,7^{a}	19,6^{ab}
A1	14,9	18,3	19,4	17,6	18,5	16,1	18,4^{a}	19,6^{a}	17,2^{b}	18,3^{b}	16,5	18,8^{a}	20,2	17,3^{b}	18,7^{a}
A2	15,0	19,1	19,2	17,4	18,2	15,8	20,5^{b}	20,9^{b}	19,5^{a}	20,2^{a}	16,8	20,6^{b}	21,0	20,3^{c}	20,6^{b}
SE^{d}	0,41	0,16	0,18	0,22	0,27	0,42	0,24	0,33	0,34	0,43	0,58	0,35	0,41	0,53	0,64
Body mass (kg)															
Diet A	574	–	573	607	590	590^{ab}	–	593^{a}	625^{a}	610^{a}	594^{a}	–	596^{a}	635^{a}	617^{a}
A1	575	–	578	608	592	578^{a}	–	582^{b}	606^{b}	595^{b}	562^{b}	–	559^{b}	575^{b}	567^{b}
A2	587	–	590	616	602	600^{b}	–	605^{c}	629^{a}	617^{a}	603^{a}	–	601^{a}	623^{a}	612^{a}
SE	1,56		1,96	3,36	5,11	2,63		3,45	4,62	5,97	3,88		4,42	5,39	7,16

$^{+}$Diet A (no urea, 55% UDP); diet A1 (1,6% urea, 41% UDP) diet A2 (1,0% urea, 47% UDP)
*All cows: (n = 21/treatment) producing ≥ 20 kg/d after 3 weeks
**High producers (n = 10/treatment) producing ≥ 30 kg/d during week 4
***Exceptionally high producers (n = 7/treatment) producing ≥ 31 kg/d during week 3
^{abc}Means in the same column with unlike superscripts differ ($P < 0,05$)
^{d}Standard error of mean

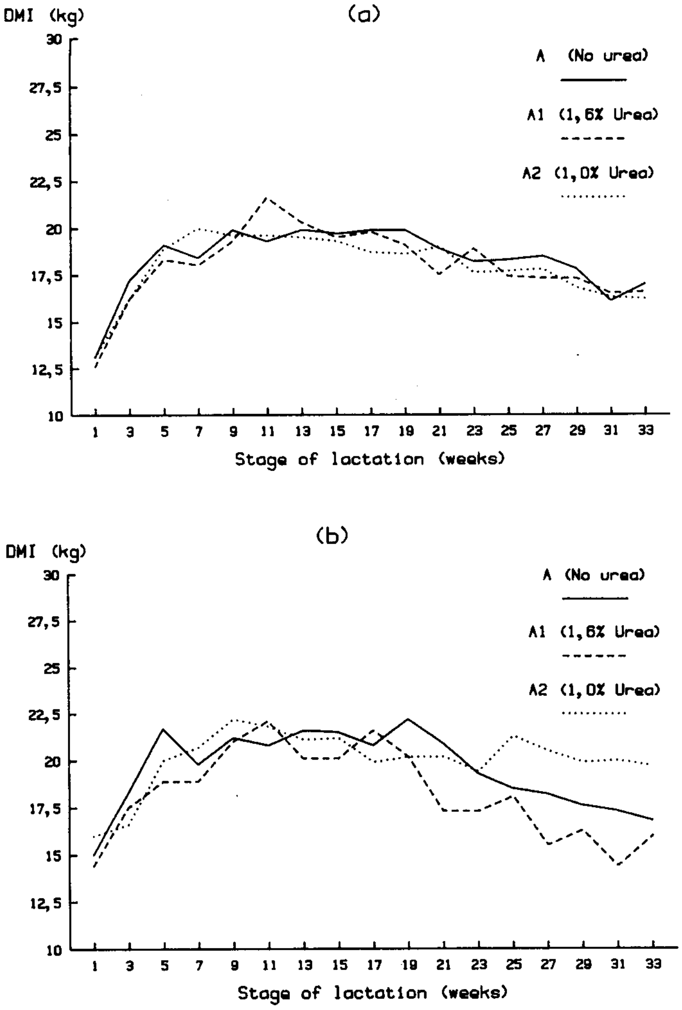

Figure 1 Mean daily DMI of cows fed diets differing in level of urea and protein degradability from week 4 through 33 of lactation. (a) All cows (AC). (b) Exceptionally high producers (EHP)

a small group with a high genetic potential for milk production combined with somewhat lower dry matter intakes probably because of the high urea content.

Flatt, Moe, Munson & Cooper (1969) have shown that over a short period some cows can produce more than 50% of total yield from body tissue. Broster, Broster, Smith & Siviter (1975) showed the regression coefficient of live mass change (kg/day) on milk yield (kg/d) to be of the order of −0,1 to −0,2 in early lactation. It is clear from the results of this study where the EHP cows lost more weight than the AC cows. The AC group receiving diets A, A1 and A2 lost 19 kg, 15 kg and 22 kg in live mass compared to the EHP group's losses of 29 kg, 26 kg and 34 kg. The average live mass during the first week post-partum was taken as reference point.

Ramage & Woolf (1973) reported that up to 1,6% urea (total diet) did not affect DMI, but van Horn & Zometa (1978) found a decreased DMI, with an inclusion of 1,7% urea (total diet), therefore 1,6% urea seems to be the maximum urea level to be considered. This is higher than the levels of 1,5 – 2,0% urea in the grain mixture or 1% of the total diet dry matter advocated by the NRC (1976). To accommodate levels of up to 1,6% urea (total diet) the feeding system followed should permit cows to eat small amounts throughout the day. A complete diet feeding system is the ideal method to dilute urea into the total diet (Kendall, 1977).

Average urea intake was 197 g/d and 289 g/d for cows receiving diets A2 and A1 respectively. Considering the NRC (1976) general guideline of 200 – 250 g urea/cow/day, this is still within acceptable limits.

Although the energy density, as ME, was low in the diets, the total intake of ME was in accordance with the ARC (1980) and was comparable to values reported by Castle & Watson (1984) and Neitz & de Bruin (1984). The intake of crude protein was sufficient to support a milk production of up to 30 kg/day (NRC, 1978).

Table 3 Mean daily milk production and composition from all cows (AC), high producers (HP) and exceptionally high producers (EHP) fed diets^{+} differing in level of urea and protein degradability

	AC group*					HP group**					EHP group***				
	Week					Week					Week				
Item	1 – 3	4 – 8	4 – 17	18 – 33	4 – 33	1 – 3	4 – 8	4 – 17	18 – 33	4 – 33	1 – 3	4 – 8	4 – 17	18 – 33	4 – 33
Milk production (kg)															
Diet A	25,9	30,0	28,5	19,7[ab]	23,8	27,7	32,9	31,6	22,9	27,0	30,6	34,0[a]	32,2	21,1[a]	26,3
A1	25,7	29,5	27,8	20,2[a]	23,8	27,8	31,9	30,5	21,6	25,8	29,2	32,1[b]	31,8	24,4[b]	27,7
A2	26,3	29,9	28,1	17,7[b]	22,6	28,3	32,6	30,9	20,9	25,7	29,7	34,3[a]	32,2	21,6[ab]	26,5
SE[d]	0,67	0,11	0,65	0,41	1,12	1,26	0,26	0,55	1,03	1,17	1,47	0,35	0,73	1,33	2,17
Butterfat (%)															
Diet A	–	–	3,00	3,02	3,01	–	–	2,94	2,92	2,93	–	–	2,88	3,01	2,94
A1	–	–	2,90	2,99	2,95	–	–	2,81	2,89	2,84	–	–	2,78	2,90	2,84
A2	–	–	3,00	3,11	3,05	–	–	2,79	3,02	2,91	–	–	2,82	2,98	2,90
SE			0,06	0,04	0,04			0,09	0,04	0,08			0,07	0,05	0,09
Protein (%)															
Diet A	–	–	3,26	3,48	3,37	–	–	3,23[a]	3,44	3,33	–	–	3,21[a]	3,46	3,33
A1	–	–	3,15	3,37	3,26	–	–	3,07[b]	3,32	3,19	–	–	3,09[b]	3,37	3,23
A2	–	–	3,20	3,40	3,30	–	–	3,22[a]	3,43	3,32	–	–	3,21[a]	3,35	3,28
SE			0,02	0,03	0,04			0,04	0,03	0,05			0,03	0,04	0,05

$^{+}$Diet A (no urea, 55% UDP); diet A1 (1,6% urea, 41% UDP) diet A2 (1,0% urea, 47% UDP)
*All cows: (n = 21/treatment) producing ≥ 20 kg/d after 3 weeks
**High producers (n = 10/treatment) producing ≥ 30 kg/d during week 4
***Exceptionally high producers (n = 7/treatment) producing ≥ 31 kg/d during week 3
[abc]Means in the same column with unlike superscripts differ ($P < 0,05$)
[d]Standard error of mean

During the first 17 weeks of lactation only the EHP cows receiving diet A1 produced significantly less milk (Table 3). This occurred during the time of peak production (week 4 – 8). The lower ME intake during peak production probably contributed to the HP and EHP cows receiving diet A1 not reaching the same peak production as the other groups. This group, however, yielded the highest milk production from week 18 – 33. The HP group showed no differences, irrespective of stage of lactation. The average decline in milk production after peak was 1,9% (diet A); 1,6% (diet A1) and 2,05% (diet A2) when all the cows were considered. Cows receiving diets A1 and A2 peaked at 4 weeks of lactation and the cows receiving diet A on week 6 of lactation. The reason for the greater decline of production by cows fed diet A2 from week 18 onwards is not known. It may be attributed to a few cows, but as no health disorders or injuries were apparent it must have been coincidental. The lactation curves of the AC group and the EHP group are shown in Figure 2.

Experiments that attempted to manipulate protein supply to the small intestine by manipulating degradability of diet protein have led to inconsistent results. However, some reports have showed apparent positive results (Oldham, Broster, Napper & Smith, 1979; Erfle, Mahadevan, Teather & Sauer, 1983; Kung & Huber, 1983; Sahlu, Schingoethe & Clark, 1984), whilst others have obtained negative results (Broderick & Lane, 1978; Mielke & Schingoethe, 1981; Grummer & Clark, 1982; Castle & Watson, 1984). Studies on milk production where diets have been formulated on estimated rumen degradability are limited. Such a study was conducted by Erdman & Vandersall (1983) who formulated concentrates to

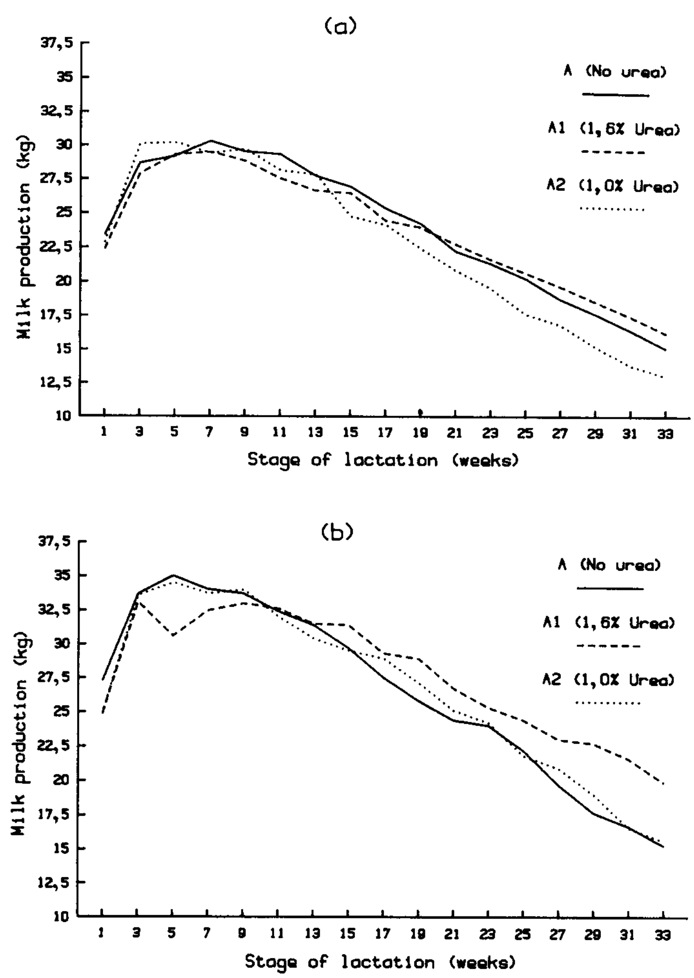

Figure 2 Mean daily milk production of cows fed diets differing in level of urea and protein degradability from week 4 through 33 of lactation. (a) All cows (AC). (b) Exceptionally high producers (EHP)

be high (73% RDP) or low (53% RDP) degradable. The milk production over 12 weeks was 35,1 kg/d and 36,0 kg/d, the differences being non significant. Vandersall & Erdman (1985) formulated complete diets to contain different percentages of protein (high (HP) or low (LP)) and RDP (low degradable (LD), medium degradable (MD) or high degradable (HD)):- HPMD : 18,1 and 57,2%; LPHD : 16,2 and 62,9; LPMD : 15,6 and 56,0; LPLD : 15,6 and 48,2. Milk yield was increased by the low protein medium degradability and low protein low degradability diets as opposed to the low protein high degradability diet, with the high protein medium degradability diet yielding the highest production. They concluded that both protein level and degradability are important in early lactation.

Three isocaloric and isonitrogenous diets with estimated RDP values of 54% (high); 49% (medium) and 43% (low) were fed to 45 Holstein cows (Forster, *et al.*, 1983). Milk production increased linearly with decreasing protein degradability. The authors observed that diets containing protein sources which are resistant to ruminal breakdown may benefit from some form of readily degradable protein, such as urea, for maximum utilization of nitrogen. Although small and not significant ($P > 0,05$) there was a tendency for increased milk production with increasing percentage UDP during weeks 4 – 17 of lactation in the present study considering the AC and HP groups. The RDP of the experimental diets in the present study was 59% (high), 53% (medium) and 45% (low), nearly the same as the experiment conducted by Forster, *et al.* (1983).

The production from week 4 – 8 showed no significant differences when the AC and HP cows were considered. However, the EHP cows receiving diet A1 produced significantly less milk with diet A2 yielding the highest production. When the five highest producers in each treatment group were considered the average milk production during week 3 – 10 of lactation was as follows: diet A — 34,5 kg/d; diet A1 — 33,9 kg/d; diet A2 — 35,2 kg/d. These data suggest that there is a tendency for the difference in milk production between treatments to increase as the production potential of the cows increases. The response was in favour of diet A2 being a combination of low (fishmeal and cottonseed cake meal) and high degradable (urea) protein sources. The same tendency was found by Sahlu, Schingoethe & Clark (1984). Only when the high producers were considered (30 kg during week 3 postpartum) a response to diets that included sources of low degradability was found.

Because lactating dairy cows cannot distinguish between the sources of N for protein synthesis, it would be beneficial to supply bacteria with NPN sources of lower cost (urea) whilst true protein of low rumen degradability would furnish amino acids to the small intestine for direct digestion and absorption. Some caution should be observed when feeding diets with large amounts of UDP, as too little ammonia might curtail optimal rumen fermentation (Kung & Huber, 1983). The present study supports this as a combination of low degradable protein sources (cottonseed cake meal and fishmeal) and high degradable sources (urea) rendered the best results when the EHP group (week 4 – 8) and the five best producers in each group (first 10 weeks) were considered. Although it was a small and non-significant response, it tended to become more significant as the production potential of the cows increased.

Although some authors (Botts, Hemken & Bull, 1977; Satter, Whitlow & Santos, 1979; Clark, 1981) have suggested that NPN (urea) should not be fed in early lactation, the results of the present study and others (Holter, *et al.*, 1968;

Foldager & Huber, 1979) contradict this view. The data from the present study and others (Erfle, *et al.*, 1983; Kung & Huber, 1983; Higginbotham, *et al.*, 1984) suggest that diets providing combinations of NPN and rumen undegradable protein might best support protein needs for high milk production as well as yielding greatest profits.

The butterfat percentage of milk was not significantly affected by treatment (Table 3). These findings were similar to others where urea replaced part of the natural protein (Foldager & Huber, 1979; Colebrander, Weiss, Hill & Moeller, 1983). However, there was a tendency for diet A1 (1,6% urea) to yield milk with the lowest butterfat content. Milk fat percentage was below the accepted average for the breeds reflecting high-energy, low-fibre diets. The pelleted complete feed also contributed to the low fat percentage. Milk protein percentage was reduced ($P < 0,05$) by the high urea diet (1,6% urea) with regard to the HP — and EHP groups, thus the concentration of milk protein decreased when diet degradability was increased. The present findings were similar to others (Clark, 1975; Ørskov, Grubb & Kay, 1977) but contrary to Erdman & Vandersall (1983) and Forster, *et al.* (1983). Erdman & Vandersall (1983) found their results surprising in that a lower degradable diet (more UDP) might be expected to provide more intestinal amino acids of higher quality for protein production in milk. This area definitely calls for further investigation.

Currently the picture of using protein degradability as a criterion for feed formulation is not clear. Until the details of this picture come into focus, common sense tells us it is nutritionally wise to include protein sources of varying rumen degradability for optimum milk production. Until more is known diets should not be balanced solely on the basis of RDP:UDP ratio and to rely upon protein sources resistant to rumen degradation as a means of lowering the total protein requirement of high producing dairy cattle does not currently seem justifiable.

Rumen fluid pH and rumen ammonia nitrogen (RAN) concentrations are presented in Table 4. Diet did not affect rumen fluid pH. The RAN concentration of cows receiving diet A1 was the highest followed by diet A2 and A. This was to be expected because of the difference in rumen degradability between diets. To achieve maximum rate of degradation of fermentable substrate Mehrez, Ørskov & McDonald (1977) showed that NH_3 concentrations in the rumen needed to be much higher than reported for maximum microbial yield (Satter & Slyter, 1974). Ørskov (1982) concluded that when ruminants are fed intermittantly, the extreme variability in RAN makes it a poor index of microbial nitrogen needs. The RAN level of 17,9 mg/100 ml when feeding diet A2 was nearly identical to the value of 17,5 mg/100 ml reported by Proctor-Howell, Vandersall, Erdman & Russel (1983) to be the optimal concentration in the rumen for protein degradation.

Feeding diets containing urea has been alleged to lower reproductive efficiency of cattle. Information presented by Huber & Kung (1981), involving 85 000 individual lactation records from Michigan DHIA herds showed that herds receiving NPN had an average calving interval identical to those fed no NPN. The average calving interval and inseminations/conception in the present study were as follows: diet A (no urea) 389 and 1,82; diet A1 (1,6% urea) 386 and 1,89; diet A2 (1,0% urea) 380 and 2,05. Neitz & de Bruin (1984) also found no detrimental effects when feeding 1,4% urea to high producing dairy cattle. The data of the present study clearly do not justify withdrawing NPN from diets for early lactation cows on the basis of poor reproductive performance.

Table 5 shows the economic evaluation of treatments by all cows based on the average milk production and DM intake during the 30-week trial. The margin over feed cost was the highest when feeding a combination of natural protein and urea. Diet A2 was the most profitable from week 4 – 17 and diet A1 from week 4 – 33. In practice, however, a change to a 12% crude protein diet (total diet) from week 17 is advocated (Neitz & de Bruin, 1984).

Table 4 Average[a] rumen fluid pH and ammonia nitrogen of cows fed diets differing in level of urea and protein degradability

Diet[b]	Rumen pH	Rumen NH_3-N (mg/dl)
A	6,12	16,6[c]
A1	6,15	22,1[d]
A2	6,10	17,9[c]

[a]Mean from 75 observations (three animals, five observations/day for five consecutive days)
[b]Diet A (no urea, 55% UDP); diet A1 (1,6% urea, 41% UDP); diet A 2 (1,0% urea, 47% UDP)
[cd]Means in the same column with unlike superscripts differ ($P < 0,05$)

Table 5 Economic evaluation from all cows (AC)[a] fed diets[b] differing in level of urea and protein degradability

Item	Diet A	Diet A1	Diet A2
Feed cost (R/cow/day)[c]			
Week 4 – 17	6,01	5,71	5,79
Week 4 – 33	5,80	5,42	5,50
Milk income (R/cow/day)[d]			
Week 4 – 17	10,83	10,56	10,68
Week 4 – 33	9,04	9,04	8,59
Margin over feed cost (R/cow/day)			
Week 4 – 17	4,82	4,85	4,89
Week 4 – 33	3,24	3,62	3,09
Relative rank			
Week 4 – 17	3	2	1
Week 4 – 33	2	1	3

[a]AC n = 21/treatment, producing ≥ 20 kg/d after 3 weeks
[b]Diet A (no urea, 55% UDP; R0,3099/kg); diet A1 (1,6% urea, 41% UDP; R0,2938/kg); diet A2 (1,0% urea, 47% UDP; R0,3018/kg)
[c]Feed cost (R/ton) *Eragrostis curvula* (160), fishmeal (690), cotton seed cake meal (400), maize meal (295), urea (397), vitamin and mineral premix (330), transport (10), pelleting (10)
[d]Milk price calculated on non quality basis

Conclusions

A level of up to 1,6% urea (total diet) would cause no fall in milk production of high producing dairy cows when included into 16% protein complete diets with an abundance (when compared to the 1980 ARC specifications) of UDP supplied. However, for exceptionally high producers the quality as well as the quantity of amino acids reaching the tissues becomes critical. From the results of this study a maximum of 1,0% urea (total diet) and supplying 47% UDP is suggested for cows of high producing potential when compared to diets providing 41 and 55% UDP. The data also suggest that diets providing combinations of urea and high quality UDP may best support the protein needs for high milk production and yield greatest profits.

Until more is known, diets should not be balanced solely on the basis of RDP:UDP ratio and to rely upon protein sources resistant to rumen degradation as a means of lowering the total protein requirement of high producing dairy cattle does not currently seem justifiable.

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