The effects of crude protein percentage and urea in different stages of lactation on milk production in high-yielding dairy cows

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Eighty-four high- and moderate-yielding Friesland/Holstein cows were divided into four groups and fed *ad libitum* complete diets with crude protein levels of: Treatment 1, 16% (4 – 33 weeks postpartum), positive control; Treatment 2, 16% (4 – 17 weeks), 12% (1,4% urea) (18 – 33 weeks); Treatment 3, 16% (4 – 17 weeks), 12% (18 – 33 weeks); and Treatment 4, 12% (1,4% urea) (4 – 33 weeks), negative control.

Milk yields for the high producers on Treatments 1, 2 and and 3 were 26,7; 26,8 and 26,1 kg/day respectively, differences being not significant. However, these cows produced significantly ($P < 0,01$) more milk than those on Treatment 4. Milk yield declined at a rate of 1,8% per week after reaching peak production for high producers on Treatments 1, 2 and 3, and 1,4% for cows on Treatment 4. Milk production for moderate producers showed the same tendency towards dietary treatment as the results obtained with the high producers.

High-producing cows on the 16% crude protein diets had a significantly ($P < 0,05$) higher feed intake between 4 – 17 weeks postpartum than cows on the 12% crude protein (1,4% urea) diet. During the 18 – 33-week period differences in dry matter intake were not significant between dietary treatments.

Results indicate that 1,4% urea can be included in complete diets for high-producing cows from the 18th week postpartum with great economic advantages.

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Volledige diëte met ru-proteïenpeile van: Behandeling 1, 16% (4 – 33 weke postpartum), positiewe kontrole; Behandeling 2, 16% (4 – 17 weke), 12% (1,4% ureum) (18 – 33 weke); Behandeling 3, 16% (4 – 17 weke), 12% (18 – 33 weke) en Behandeling 4, 12% (1,4% ureum) (4 – 33 weke), negatiewe kontrole is *ad lib.* aan 84 hoog- en middelmatig-produserende Fries/Holstein-koeie gevoer.

Die hoog-produserende koeie het op Behandelings 1, 2 en 3 'n gemiddelde daaglikse produksie van 26,7; 26,8 en 26,1 kg respektiewelik gelewer. Hierdie verskille was nie betekenisvol nie. Laasgenoemde koeie het betekenisvol ($P < 0,01$) beter geproduseer as koeie op Behandeling 4. Melkproduksie het in die geval van die hoë produseerders op Behandelings 1, 2 en 3 teen 'n tempo van 1,8% per week gedaal, na bereiking van piekproduksie, teenoor die 1,4% produksie-daling vir koeie op Behandeling 4. Melkproduksie van die middelmatige produseerders het dieselfde tendens teenoor dieetbehandelings getoon as die resultate verkry met hoë produseerders.

Hoog-produserende koeie het tussen 4 – 17 weke postpartum 'n betekenisvolle ($P < 0,05$) hoër voerinname op die 16% ru-proteïen dieet, getoon as koeie op die 12% ru-proteïen (1,4% ureum) dieet. Gedurende week 18 – 33 van laktasie het geen betekenisvolle voerinname-verskille, ongeag dieetbehandeling, voorgekom nie. Hierdie resultate toon duidelik dat 1,4% ureum in volledige diëte vir hoog-produserende koeie, vanaf die 18de week postpartum, met hoë ekonomiese voordele ingesluit kan word.

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Keywords: High milk producers, urea, complete diets, stage of lactation.

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Introduction

Despite many investigations there is little agreement on those dietary conditions which will ensure effective use of added NPN in diets for dairy cows (Kwan, Coppock, Lake, Fettman, Chase & McDowell, 1977). The lack of agreement can be ascribed to several factors e.g. genetic potential for milk production, differences in feed or energy intake, type of protein source, length of experimental period, or part of the lactation cycle used for experiments (Lindell, 1982).

From results of *in vitro* studies with continuous culture fermentors, Satter and Slyter (1974) found maximum ammonia-nitrogen (RAN) concentration of 5 mg/100 ml rumen fluid. It was noted that rumen ammonia exceeded 5 mg/100 ml whenever dietary protein was higher than 12 – 13% (Roffler & Satter, 1975). Consequently, Kwan *et al.* (1977) concluded that diets containing more than 13% natural protein could not be improved by additions of NPN. Since high-producing dairy cows require diets containing 16% crude protein (CP), urea would not be useful in such diets. Cows requiring a high percentage of dietary protein (16% CP) probably can only use urea efficiently in diets having more than 12 – 13% CP when a higher amount of protein passes through the rumen without being degraded (Miller, 1979). However, it should be possible to reduce the concentration of dietary CP below 16% once cows have reached peak intake of dry matter (DM) and energy balance (Roffler & Thacker, 1983). Cows in mid- and late-lactation were found to perform as well when fed a diet containing 11% CP as when fed one containing 12 – 14% (Thomas, 1971). These results suggest that in mid- and late-lactation the CP content of the diet could be reduced from 16% to 11 – 12% with urea as the only source of supplementary protein. It has commonly been accepted that urea can be given to dairy cows up to a level that would (i) supply 35% of the total nitrogen in the diet, (ii) constitute up to 3% of the concentrate mixture, or (iii) constitute as much as 1% of the total diet DM (Van Horn, Foreman & Rodriguez, 1967). These recommended levels would probably avoid toxicity and give satisfactory performance. However most of the data reviewed to arrive at these conclusions dealt with cows producing less than 20 kg milk daily. It is possible that higher producing cows may respond differently.

The objective of the present experiment was to examine effects of utilizing urea in early- and mid-lactation and the percentage of CP in complete diets fed to high- and moderate-yielding cows during different stages of lactation.

Procedure

The experiment included a standardization period (SP) (week 1 – 3 postpartum) and two experimental periods (EP), EP1 (week 4 – 17) and EP2 (week 18 – 33).

Eighty-four lactating Friesland/Holstein cows were fed *ad libitum* a complete diet with crude protein 16% (Diet A) in the standardization period (Table 1). At week 3 postpartum the cows were grouped into a high-production group (HP) (comprising 44 cows with a daily average of between 26 and 35 kg milk in the SP) and a moderate-production group (MP) (comprising 40 cows averaging between 20 and 26 kg milk). Cows in each production group were assigned randomly to four experimental treatments:

Treatment 1: 16% crude protein (Diet A) (EP1 and EP2), positive control;
Treatment 2: 16% crude protein (Diet A) (EP1) and 12% crude protein (1,4% urea) (Diet B) (EP2);
Treatment 3: 16% crude protein (Diet A) (EP1) and 12% crude protein (Diet C) (EP2); and
Treatment 4: 12% crude protein (1,4 urea) (Diet B) (EP1 and EP2), negative control.

Table 1 Formulation and composition of experimental diets

	Diets		
	A	B	C
Components			
Eragrostis curvula hay, %	38,0	42,0	42,0
Yellow maize meal, %	41,0	53,6	46,0
Fishmeal, %	9,0	–	4,5
Cottonseed oil cake meal, %	9,0	–	4,5
Urea, %	–	1,4	–
Minerals, %	3,0	3,0	3,0
Composition			
Dry matter, %	90,4	90,3	90,5
Crude protein, %	16,2[a]	12,2[b]	12,1[b]
Digestible protein, %	11,4[a]	8,5[b]	8,3[b]
Fibre, %	15,6	15,4	15,4
Metabolizable energy, MJ/kg DM	9,3	9,5	9,3

[a,b] Means in a line having the same superscript do not differ significantly ($P < 0,1$).

Experimental diets comprised pelleted complete diets having a ratio of *Eragrostis curvula* hay to concentrate of 40:60 (Table 1). Cows were fed individually *ad libitum* levels using electronic feeding doors. The cows were housed in a deep-litter system. In addition, three lactating Friesland/Holstein cows were used to determine the digestibility of the experimental diets in a 3 × 3 Latin-square experiment.

Results and Discussion

The composition of the experimental diets is given in Table 1. The CP content of Diet A was significantly higher than that of Diets B and C. The estimated metabolizable energy (ME) values were similar for all three diets at 9,3; 9,5 and 9,3 MJ/kg DM respectively. The mean apparent digestibility coefficients of the components of the diets showed no significant differences (Table 2). Mean daily intake of dry matter (DM) and ME are given in Table 3.

Figure 1 depicts means of daily DM intake plotted weekly.

Table 2 Mean apparent digestibility coefficients of the components of experimental diets consumed by the lactating cows during the digestion trial

	Diets		
Component	A	B	C
Dry matter, %	63,0	66,2	63,1
Energy, %	61,2	65,9	62,5
Crude protein, %	70,3	69,5	68,8

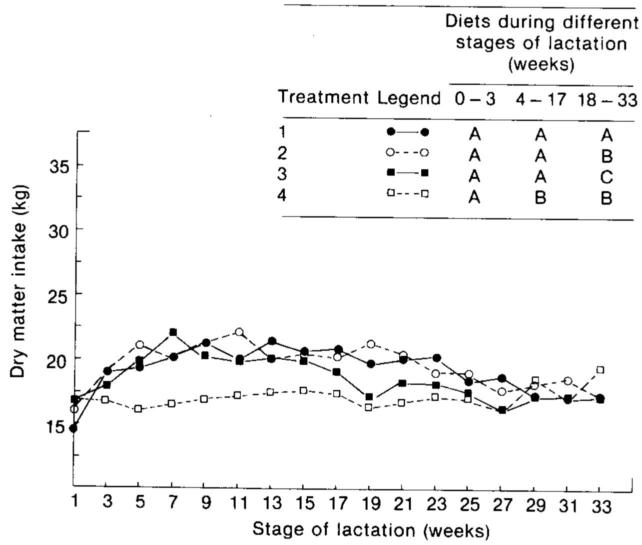

Figure 1 Mean daily DM intake of high-yielding dairy cows fed varying percents protein during different stages of lactation where Diet A (16% CP), Diet B (12% CP; 1,4% urea), and Diet C (12% CP)

Cows in the HP group on Diet A had a significantly higher feed consumption in EP1 than those on Diet B. Kung & Huber (1983) showed that dry matter intake for cows fed 11,3; 14,5 and 17,5% protein increased with increasing protein level, averaging 16,5; 19,1 and 20,8 kg/day respectively during early lactation. Protein needs for lactating cows are greatest in early lactation when milk yields are highest. During EP2 differences in feed intake for cows on Diets A, B or C were not significant. Differences in DM intake of cows on Treatments 1, 2, 3, and 4 were not significant when assessed over the entire lactation of 33 weeks. Urea intake varied between 246 and 274 g/day for cows on Treatments 2 and 4 which is 1,3 times higher than the guideline recommended by the National Research Council (NRC) (1976), but within acceptable limits. Differences in ME intake for cows in the HP group were not significant irrespective of the dietary treatment within each experimental period or the entire lactation. ME intake values were comparable to values reported by Neitz, van Zyl & Hartman (1981). Cows in the MP group showed no significant differences in DM intake and ME intake, within the dietary treatment × experimental period and entire lactation (Table 3).

Cows in the HP group receiving Diet A in the EP1 produced more milk ($P < 0,01$) than those receiving Diet B (Table 4). Similar results were reported by Edwards, Bartley & Dayton (1980) and Kung & Huber (1983). Satter & Roffler (1975) suggested that diets for cows in early lactation be supplemented with only natural protein to 16% CP. However, the concept

Table 3 Mean daily intake of DM and ME for high-producing (HP) and moderate-yielding (MP) cows fed complete diets varying in protein level from different sources

	Mean values for diets⁺ and periods* on															
	Treatment 1				Treatment 2				Treatment 3				Treatment 4			
	A	A	A	–	A	A	B	–	A	A	C	–	A	B	B	–
Item	SP	EP1	EP2	Mean	SP	EP1	EP2	Mean	SP	EP1	EP2	Mean	SP	EP1	EP2	Mean
HP group																
DM, kg	16,1	$20,7^{abc}$	19,0	19,7	16,3	$20,9^{bac}$	19,1	19,6	15,6	$20,0^{cab}$	17,8	18,5	16,0	$17,6^{d}$	17,4	17,4
ME, MJ	149,7	192,5	176,7	183,2	151,6	194,4	181,4	184,2	145,0	186,0	165,5	172,0	148,8	167,2	165,3	164,6
MP group																
DM, kg	14,3	18,7	17,0	17,4	15,3	18,9	17,5	17,9	15,8	19,9	18,3	18,8	14,1	17,5	16,6	16,7
ME, MJ	132,9	173,9	158,1	161,8	142,3	175,8	166,3	168,1	146,9	185,1	170,2	174,8	131,1	166,3	157,7	158,9

⁺ Diet A (16,2% CP); Diet B (12,2% CP; 1,4% urea); Diet C (12,1% CP).

* SP (weeks 0 – 3); EP1 (weeks 4 – 17); EP2 (weeks 18 – 33); mean (weeks 0 – 33).

a,b,c,d Means in a line and corresponding stage of lactation having the same superscript do not differ significantly ($P < 0,05$).

Table 4 Mean daily milk production and composition of milk of high-yielding (HP) and moderate-yielding (MP) cows fed complete diets varying in protein level from different sources

	Mean values for diets⁺ and periods* on															
	Treatment 1				Treatment 2				Treatment 3				Treatment 4			
	A	A	A	–	A	A	B	–	A	A	C	–	A	B	B	–
Item	SP	EP1	EP2	Mean	SP	EP1	EP2	Mean	SP	EP1	EP2	Mean	SP	EP1	EP2	Mean
HP group																
Milk, kg	29,1	$32,4^{abc}$	22,0	$26,7^{abc}$	28,9	$31,8^{bac}$	21,6	$26,8^{bac}$	29,5	$31,8^{cab}$	21,9	$26,1^{cab}$	28,9	$26,9^{d}$	19,4	$23,1^{d}$
4% FCM, kg	27,6	25,9	18,4	22,4	27,8	26,2	17,9	22,2	28,2	26,0	18,4	21,7	27,9	23,7	17,2	20,7
Butterfat, %	3,6	$2,7^{efg}$	2,9	$2,9^{efg}$	3,8	$2,8^{feg}$	2,9	$2,9^{feg}$	3,6	$2,8^{gef}$	2,9	$2,9^{gef}$	3,8	$3,2^{h}$	3,2	$3,3^{h}$
Protein, %	3,5	3,1	3,4	3,3	3,3	3,2	3,2	3,2	3,7	3,2	3,5	3,3	3,5	3,1	3,3	3,3
MP group																
Milk, kg	23,6	$25,6^{abc}$	16,3	$20,7^{abc}$	23,1	$24,9^{bac}$	15,2	$19,7^{bac}$	23,0	$25,2^{cab}$	16,4	$20,6^{cab}$	23,6	$21,9^{d}$	15,5	$18,8^{d}$
4% FCM, kg	23,5	21,9	14,1	18,1	21,6	20,7	13,4	16,9	21,4	20,6	14,0	17,5	21,6	19,4	13,4	16,7
Butterfat, %	3,8	$3,1^{efh}$	3,1	3,2	3,4	$2,9^{fegh}$	3,2	3,0	3,6	$2,8^{gf}$	3,0	3,0	3,6	$3,2^{hef}$	3,1	3,3
Protein, %	3,8	3,2	3,5	3,4	3,7	3,2	3,4	3,3	3,6	3,3	3,4	3,5	3,5	3,1	3,3	3,3

⁺ Diet A (16,2% CP); Diet B (12,2% CP; 1,4% urea); Diet C (12,1% CP).

* SP (weeks 0 – 3); EP1 (weeks 4 – 17); EP2 (weeks 18 – 33); mean (weeks 0 – 33).

a,b,c,d Means in a line and corresponding stage of lactation having the same superscript do not differ significantly ($P < 0,01$).

e,f,g,h ($P < 0,05$).

that supplemental urea may have little or no value in diets containing 12 – 13% CP appears to be inconsistent with this. Cows requiring a high percentage of dietary protein probably can use urea efficiently in certain diets having more than 12 – 13% CP, when more protein passes through the rumen without being degraded (Miller, 1979). The 16% protein level recommended by the NRC (1976) appears to be adequate for cows producing up to 30 kg milk per day in early lactation. A diet containing 13% protein was insufficient for cows producing up to 29 kg of milk per day when compared with these standards (Edwards *et al.,* 1980). There was no significant difference in production between Diets A, B and C when fed in EP2 (weeks 18 – 33). According to Satter & Roffler (1975) supplemental NPN would be satisfactory for mid-and late-lactation (after 14 weeks postpartum) for diets containing 12,5% CP. Over the entire lactation, cows on Treatments 1, 2 and 3 produced significantly ($P < 0,01$) more milk than those on Treatment 4 (Figure 2). As shown in Figure 2 milk yield declined at a rate of 1,8% weekly after reaching peak production for high producers on Treatments 1, 2 and 3 and 1,4% for cows in Treatment 4. The decline in production found in

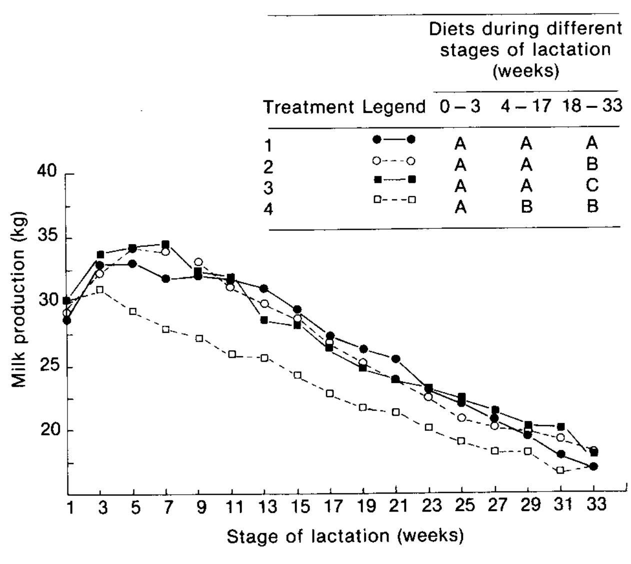

Figure 2 Mean daily milk production of high-yielding dairy cows fed varying percents protein during different stages of lactation where Diet A (16% CP), Diet B (12% CP; 1,4% urea), and Diet C (12% CP)

Table 5 Mean body mass, and calving interval of high-yielding (HP) and moderate-yielding (MP) cows fed complete diets varying in protein level from different sources

	Mean values for diets⁺ and periods* on															
	Treatment 1				Treatment 2				Treatment 3				Treatment 4			
Item	A SP	A EP1	A EP2	– Mean	A SP	A EP1	B EP2	– Mean	A SP	A EP1	C EP2	– Mean	A SP	B EP1	B EP2	– Mean
HP group																
Body mass, kg	576	602	638	617	567	566	589	578	590	581	606	595	589	558	576	570
Calving interval, days	–	–	–	389	–	–	–	396	–	–	–	412	–	–	–	399
MP group																
Body mass, kg	547	546	580	563	580	584	621	603	558	588	639	612	543	543	568	556
Calving interval, days	–	–	–	400	–	–	–	381	–	–	–	381	–	–	–	373

⁺ Diet A (16,2% CP); Diet B (12,2% CP; 1,4% urea); Diet C (12,1% CP).
* SP (weeks 0–3); EP1 (weeks 4–17); EP2 (weeks 18–33); mean (weeks 0–33).

this study is far less than the normal 2,5% weekly decline in milk yield as reported by Broster, Sutton & Bines (1978). These data suggest that the CP and ME levels in the present study were adequate (NRC, 1976) to maintain a high production in mid-to late-lactation. Results of dietary treatments regarding milk production for cows in the MP group showed the same tendency as those obtained in the HP group.

Means for butterfat and milk protein contents are given in Table 4. The percentage of butterfat was low for all diets, probably owing to a lack of long fibre. Although changes in body mass do not necessarily reflect changes in body reserves, Table 5 indicates that dietary treatments had no significant influence on the body mass of cows in the HP and MP groups. Edwards *et al.* (1980) reported that body mass, services per conception, or days cows were open did not differ between dietary protein concentrations.

Differences in mean calving interval in the present study were not significant (Table 5) and were well below the average of 409 days for grade Friesland cows in the Republic of South Africa (Department of Agriculture, 1983).

Conclusions

From the present study it appears that the inclusion of 1,4% urea in complete diets, in order to obtain a dietary concentration of 12% crude protein in the total diet, can be applied with great biological and probably economical success from the 18th week postpartum.

However, the 12% crude protein (1,4% urea) diet could not supply sufficient protein for high- and moderate-yielding cows fed *ad libitum* in early- to mid-lactation. This is based on reduced intake in early- to mid-lactation (4–17 weeks) for high-producing cows and reduced milk production for high- and moderate-producing cows fed diets containing 12% crude protein (1,4% urea) compared with those receiving 16% crude protein at the same stage of lactation.

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