Relationship Between Content of Crude Protein in Rations for Dairy Cows and Milk Yield, Concentration of Urea in Milk and Ammonia Emissions

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ABSTRACT

During recent decades, efforts have been made in several countries to diminish the negative environmental influence of dairy production. The main focus has been on nitrogen and phosphorus. Modern dairy production in Western Europe is often based on imported feedstuffs, mostly protein-rich feeds. In Sweden at least, it is wished that the use of imported feedstuffs in animal production will decrease due to the risk of contamination with *Salmonella* and the ban of using GMO crops in Swedish dairy production.

An experiment was carried out to investigate whether a lower content of crude protein in the diet would decrease the ammonia release from cow manure and whether a well-balanced diet using only feedstuffs of Swedish origin would maintain milk production.

Five treatments were arranged in a Latin square design. Two different protein supplements made of ingredients of Swedish origin were each fed at two protein levels, and a fifth imported commercial protein mix was fed at the higher level. The treatments with low protein levels (13.1 to 13.5%) had a significantly lower milk yield, kilograms of ECM, but, on the other hand the net profit, milk income minus feed cost was nearly the same in all treatments except diet C, which had lower feed cost but also lower net profit due to lower milk yield. The content of urea in milk was higher with diets high in crude protein (17%) content. A decreased protein level in the diets did not influence the content of casein or whey protein, but the commercial concentrate showed a tendency to give lower values than the Swedish mixtures. The low protein diets gave significantly lower ammonia release from manure compared with the high protein diets. There were no production differences between the diets of Swedish feeds compared with the imported control. The readily fermentable beet pulp should have helped cows use the higher N diet more

efficiently and increased the response. This gives the rumen microbes a possibility to match the inflow of protein with carbohydrates. Income over feed costs shows that it is possible to compile diets using products of Swedish origin and still be competitive. On the other hand, this structure may change quickly due to altered world market prices.

(Key words: dairy production, ammonia emission, urea, protein content)

Abbreviation key: **AAT** = amino acid absorbed in the intestine, **ECM** = energy-corrected milk, **ECP** = endogenous protein, **EPD** = rumen degradability, **GMO** = genetically modified organisms, **MP** = metabolizable protein, **PBV** = protein balance in the rumen, **SEK** = Swedish crown.

INTRODUCTION

During recent years, the goal of dairy production has widened to include economic, environmental, and animal welfare concerns (Klint Jensen and Sørensen, 1999). In Europe, considerable efforts have been made to decrease the environmental influence from the whole livestock sector, for example in the Netherlands, Denmark, and Sweden (Kuipers and Mandersloot, 1999; Jakobsson, 1999). Also, in the United States, a process has started to diminish the environmental problems caused by animal production, and this process seems to be accelerating (Nelson, 1999; Meyer et al., 1999). Initially, the focus has been on nitrogen and phosphorus (Chalupa and Ferguson, 1996). In the cowshed, the biggest problem with nitrogen is the emission of ammonia from urine and dung. In Sweden, the livestock sector is responsible for 90% of the ammonia emissions (50,200 tonne per year) and cattle alone for 64% or 32,300 tonne per year (Jakobsson, 1999). Ammonia emission from the cattle sector in Denmark is 28,000 tonne per year. In England and Wales, 42,200 tonne per year originate from housing and storage alone (Hutchings et al., 2001; Webb, 2001). In dairy production, most efforts have been concentrated on the development of technical solutions in the stable to decrease ammonia emission, for

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example, floor design or roofs on slurry tanks (Swiestra et al., 2001). However, the greatest inflow of nitrogen to a dairy farm is from four main sources; nitrogen from mineral fertilizer, nitrogen from purchased feedstuffs, nitrogen from fixation by legumes, and nitrogen from the atmosphere (Aarst et al., 1992; Kohn et al., 1997; Cederberg et al., 2000).

The release of ammonia from manure depends on the content of nitrogen. A decrease in the content of nitrogen in manure decreases the emission of ammonia—this relationship is linear (Elzing and Monteny, 1997). The content of nitrogen in manure depends on the feed ration and the feeding strategy of the cow (Chalupa and Ferguson, 1996; Dou et al., 1996; Tomlinson et al., 1996; Paul et al., 1998; Chase, 1999; Godden et al., 2001). James et al. (1999) investigated ammonia volatilization from manure from Holstein heifers, and concluded that increased dietary CP concentration increased nitrogen intake, nitrogen excretion, urea nitrogen excretion, and nitrogen excreted in the urine by the heifers.

During recent decades, the content of protein in the feed ration of dairy cows has been studied more closely (NRC, 2001). Several countries have developed feed evaluation systems, which divide CP into several fractions, depending on the degradation in the rumen (Madsen, 1985). In the beginning of the 1990s, two circumstances in Sweden influenced the protein content in feed rations. Firstly, a new feed evaluation system for dairy cattle was introduced in Sweden and in other Nordic countries—the AAT/PBV system (Madsen, 1985; Magnusson et al., 1990; Madsen et al., 1995). The **AAT** stands for amino acids adsorbed in the intestine and **PBV** for protein balance in the rumen. Secondly, import tariffs on protein-rich concentrates were removed in Sweden (Gran et al., 1993), making these feedstuffs cheaper. These two occurrences in combination cooperated to increase both the percentage content and the total amount of protein in the feed rations (Gustafsson, 2000). Dairy production in Sweden, as shown by Cederberg and Mattsson (2000), is dependent on imported feedstuffs. Due to uncertainty about the hygienic quality of imported feedstuffs, there is increasing interest in Sweden in relying on feedstuffs of domestic origin. Imported feedstuffs may be infected with *Salmonella*, might carry infectants from mad cow disease or be polluted by dioxins. Another problem is the use of **GMO** (genetically-modified organisms) crops, which are banned as feedstuffs in Swedish dairy production by a voluntary agreement between Swedish dairies and the Swedish feed industry (LRF, 2001). The Swedish environmental policy includes biological diversity as a special goal (The Swedish government, 2000). The largest single imported protein feed in Swedish

animal production is soybean meal. Cultivation of soybean often leads to problems with soil erosion and, in the worst cases, to exploitation of tropical rain forest. This is in conflict with the goal of biological diversity (Cederberg, 2001). Therefore, it seems to be of vital interest to decrease the amount of imported feedstuffs with the aim of producing milk mainly by using Swedish feedstuffs.

Aim of Present Study

The objectives of this study were to test the following hypotheses:

Hypothesis 1: A lower content of CP in the diet should decrease the ammonia release from cow manure.

Hypothesis 2: A well-balanced diet with feedstuffs of Swedish origin should not decrease the milk yield.

MATERIALS AND METHODS

Feeding

Five different rations, named A, B, C, D, and E, were compared in the Latin square test. Diets A, B, and D had high protein levels (17% CP in total DM), and diets C and E had a low protein level (13.1 to 13.5% CP). The protein levels were about 1% lower than initially planned, due to divergent protein content in roughage compared with preliminary analyses. The roughage base consisted of hay, grass silage, and super-pressed beet pulp silage. Concentrates of two types were administered according to actual milk yield. The base concentrate consisted of grain, while the second concentrate consisted of one of three different protein supplements. The five diets are presented in Table 1, and the different concentrates in Table 2. In ration A, commercial protein supplement was used as a control, while in the other diets two different supplements (SWE 1 and SWE 2) were used, based only on ingredients produced in Sweden.

The protein content in the different rations was regulated partly by the concentrates and partly by the roughage, mostly beet pulp, which was increased when lowering the level of CP.

We do not know the exact composition of the commercial blend, but as a rough estimate, the feed factory—producing about 90% of total commercial concentrates in Sweden—stated that the soy products will amount to 30 to 35%, rapeseed products to 20 to 25%, other protein sources such as brewer's grain, peas, and palm kernel meal to 20 to 25%, beet fiber and molasses to 10 to 15% and others such as fat, vitamins, and minerals 0 to 5%. About 50% of the supplement have probably been imported.

Table 1. Feeding regime of roughages and concentrates, kg per day; live weight 650 kg.

Protein level Protein conc.	Feed ration									
	A High Control		B High SWE 1		C Low SWE 1		D High SWE 2		E Low SWE 2	
Roughage										
Grass hay	1		1		1		1		1	
Grass silage, DM ¹	7		7		6.5		7		6.5	
Beet pulp silage, DM ²	2.5		2.5		5		2.5		5	
Concentrate after milk production, kg	Base	Comm.	Base	SWE 1	Base	SWE 1	Base	SWE 2	Base	SWE 2
Energy-corrected milk										
15	0.1	2.3		2.5		0.2		2.7	0.2	0.1
20	1.3	3.3	0.9	3.6	1.6	0.7	0.5	4.0	1.9	0.7
25	2.6	4.3	1.9	4.7	3.3	1.2	1.5	5.2	3.5	1.2
30	3.8	5.3	3.0	5.8	5.0	1.8	2.4	6.5	5.2	1.8
35	5.0	6.3	4.1	7.0	6.7	2.3	3.4	7.7	6.9	2.4
40	6.3	7.3	5.2	8.1	8.4	2.9	4.3	9.0	8.5	3.0
45	7.5	8.3	6.3	9.2	10.1	3.4	5.2	10.3	10.2	3.6

¹75% grass and 25% clover, ensiled in bunker silos, 30% DM.²Super-pressed beet pulp mixed with 5% molasses and ensiled, 27% DM.

Animals and Management

Twenty dairy cows (Swedish Holstein) from the experimental dairy herd were used in the experiment. When half of the cows had calved, they were randomly grouped into two blocks (1 and 2) and the feeding experiment could start, with cows in their first month of lactation. The same procedure was repeated 1 mo later with the other 10 cows in blocks 3 and 4 (Table 3). The cows were in their second or later lactation. They were kept in tie stalls and milked twice daily. The barn at the experimental farm was equipped with mobile feed carriers for individual feeding of all feedstuffs. Roughages were fed twice a day and concentrate mixtures four times daily. Feed refusals were weighed every morning.

As mentioned earlier, five different treatments were tested. The design of the experiment is given in Table 3. Each period extended over 6 wk; the first 2 wk were

preexperimental to get the cow adapted to the new feeding regimen. Total daily amounts of feces and urine were collected together from individual cows in blocks 1 and 3, during 4 d in the last week of each period.

Registrations and Analyses

Feeds. Samples of silages were collected every day and frozen for later analysis of pooled 2-wk samples. Samples of concentrate ingredients and blends were taken on each mixing occasion. Samples were pooled for 4 wk. Chemical analyses were made on pooled samples, and nutrition values were calculated according to standard methods (Spörndly, 1995). Analyses and feed values are presented in Table 4.

Milk. Individual milk recording with milk sampling was done 2 d weekly. Pooled milk samples were analyzed every week at a commercial dairy laboratory. The

Table 2. Recipe of concentrate mixtures, percent of mixture.

	Mixture		
	Base	SWE 1	SWE 2
Barley	45		
Oats	25		
Wheat	30		
Peas		22.5	22.5
Rapeseed meal, heat-treated		15.0	20.0
Rapeseed expeller, heat treated		35.0	15.0
Dried brewer's grain		12.5	15.0
Dried beet pulp fiber		15.0	15.0
Linseed cake			12.5
Price, Swedish crowns, SEK/kg ¹	1.30	1.87	1.99

¹Calculated with prices as per September, 2001.

Table 3. Block design. A, B, C, D, E refer to different diets.

Block	1 ¹					2				
Period 1	A	B	C	D	E	A	C	B	D	E
Period 2	B	C	D	E	A	C	E	D	A	B
Period 3	C	D	E	A	B	B	D	A	E	C
Period 4	D	E	A	B	C	E	A	C	B	D
Period 5	E	A	B	C	D	D	B	E	C	A
Block	3 ¹					4				
Period 1	A	C	E	D	B	C	B	E	D	A
Period 2	E	A	C	B	D	A	C	B	E	D
Period 3	D	B	A	C	E	D	A	C	B	E
Period 4	B	E	D	A	C	E	D	A	C	B
Period 5	C	D	B	E	A	B	E	D	A	C

¹Manure was collected.

contents of true protein, fat, lactose, urea, and SCC in milk were analyzed by the infrared technical instrument Foss Combi (Foss Electric AS, Denmark). The reference methods were as follows for fat: Röse Gottlieb, IDF standard ID, 1996; for protein: Kjeldahl IDF standard 20B, 1993 part 3; and for SCC, direct count in microscope, IDF standard 148A, 1995. Lactose and urea estimations were based on national and international ring tests.

Live weight. The cows were weighed in the beginning of the trial and at the end of each period. The body condition was scored at the beginning of the trial and after the whole trial was finished.

Manure. During four consecutive days in the last week of each period, plastic bins were placed in the manure channel behind each cow in blocks 1 and 3 for total collection of individual feces and urine for 24 h at a time. The collected amount was thoroughly mixed, and a sample was frozen for chemical analyses. During

these days, the cows were separated by empty tie stalls in order to avoid a mixture of manures.

Frozen samples of manure were analyzed at a commercial agricultural laboratory. The DM was analyzed (Ref. SS 028113) together with the contents of total N (Ref. SS 028101:1-92 mod) and NH₄-N (Ref. KKK 7 1950 mod). Total N and NH₄-N were estimated in wet material to avoid losses of ammonia.

About one third of the fresh manure was put in a plastic bin, and the ammonia release was estimated with a ventilated chamber, constructed at the department. This analytical technique to determine ammonia release from feces and urine has been described by Andersson (1994). Ammonia concentrations in the chamber air were measured with reagent tubes (Kitagawa). The ventilation rate through the chamber was determined by measuring the pressure difference over an orifice plate. To eliminate errors caused by variations in ventilation rate, all determinations were made at a

Table 4. Chemical analyses and calculated nutrient contents in feeds.

	Hay		Grass silage		Beet pulp silage		Base		SWE 1		SWE 2		Commercial blend ¹	
	LSM	SD	LSM	SD	LSM	SD	LSM	SD	LSM	SD	LSM	SD	LSM	SD
Number of analyses	8		9		8		8		7		7		7	
DM, %	84.8	1.2	30.1	2.2	26.4	0.8	87.2	0.0	89.2	0.00	89.1	0.00	88.5	1.1
In % of DM														
CP	13.0	1.4	16.3	2.0	9.7	2.6	11.0	3.2	27.8	0.4	27.3	0.04	27.8	0.6
Crude fat	2.4	2.1	2.7	0.5	1.0	0	4.1	0.4	8.5	0.4	9.3	0.9	8.8	0.3
Ash	7.5	0.5	8.4	0.5	7.2	0.7	2.6	0.3	6.0	0.1	5.8	1.2		
NDF	56.3	3.0	45.8	5.9	43.7	1.4	19.6	4.8	28.2	1.1	28.6	1.8	31.5	
Starch							59.7	4.6	12.2	1.0	12.2	1.0	8.1	1.5
Per kg of feed														
MJ metabolizable energy	8.82	0.30	3.28	0.24	3.41	0.06	11.79	0.12	12.32	0.14	12.35	0.13	12.0	
AAT ² g	61	0.4	22	0.9	27	2.0	73	3.4	123	10.3	115	8.6	140	
PBV ³ g	6	1.1	12	5.1	-19	2.8	-22	6.3	67	27.3	70	13.8	30	
CP, g	110	12.1	49	6.1	26	0.9	97	2.8	248	4.0	243	8.7	246	

¹Partly from chemical analyses, partly guaranteed values.²AAT = Amino acid absorbed in the intestine.³PBV = Protein balance in the rumen.

Table 5. Total amount of consumed nutrients in the different treatments.

	Control	Concentrate SWE 1		Concentrate SWE 2	
	A	B	C	D	E
Level of protein	High	High	Low	High	Low
CP%	17	16.6	13.1	17	13.5
DM, kg	20.3	20.4	19.9	20.3	19.1
CP, g	3451	3387	2615	3448	2572
Fat, g	893	855	587	911	602
NDF, g	7252	6946	6744	6941	6475
Starch, g	3035	3000	3990	2654	3808
AAT, ¹ g	2040	1906	1692	1861	1633
PBV, ² g	133	366	-173	449	-122
MJ metabolizable energy	244	239	234	238	225

¹AAT = Amino acid absorbed in the intestine.²PBV = Protein balance in the rumen.

ventilation rate of 100 m³/m²h and at a room temperature close to 16°C. The intention with the applied method for estimation of ammonia release is mainly to express the relative differences between feed rations, not to give the exact values of ammonia release per cow and day.

Statistical Analysis

The experimental design was Latin square. The analyses were made using the SAS statistical package (SAS, 1986). As values of somatic cells are not in normal distribution, they were transformed in logarithmic scale before the statistical analysis.

$$Y_{ijklm} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_l(\alpha_i)_i + (\beta \gamma)_{jk} + e_{ijklm}$$

Y_{ijklm} = Milk: yield (kg/day), fat %, protein %, lactose %, casein %, whey protein % NPN %, urea (mmol/l), casein, NPN, soluble nitrogen, total nitrogen, whey protein;

Manure = Manure: DM, ammonia kilogram per tonne manure, total amount of nitrogen per tonne manure, soluble nitrogen per tonne manure, NPN, organic nitrogen in manure;

α_i = block;

β_j = period;

γ_k = treatment (diet);

$\delta_l(\alpha_i)$ = cow within block;

$(\beta \gamma)_{jk}$ = interplay between period and treatment; and

e_{ijklm} = random effect.

RESULTS

Feed Consumption

The average daily feed consumption is presented in Table 5. The diets fulfilled the need of metabolizable energy and CP but was not optimized due to AAT and PBV.

Milk

No significant differences in yield of milk or **ECM** (energy-corrected milk with 4% fat and 3.4% protein) were observed between the different protein supplements at high protein level (A, B, and D). The low protein levels (C and E) resulted in lower yields, especially in the amount of milk (Table 6). The content of milk protein was significantly lower in the control diet A, compared with all other diets. Milk fat was not significantly affected. However, slightly higher concentrations of different milk constituents, when low protein concentrations were fed, resulted in only small differences between diets in daily yields of milk fat and milk protein. The content of urea was significantly higher ($P < 0.0001$) in treatments with high CP level in the diet.

The results of analyses of different nitrogen fractions in morning milk sampled in blocks 1 and 3 during the weeks of manure collection are presented in Table 7. Total N was significantly lower for diet A. The NPN was significantly higher at high protein level in the diet. The contents of casein and whey were influenced by protein level in the diet. Thus, the high level, especially with the commercial concentrate, decreased both casein and whey content.

Nitrogen Efficiency

In Figure 1, the nitrogen efficiency is presented, calculated as N from true milk protein in percentage of

Table 6. Average daily milk yield at different diets.

		Control	Concentrate SWE 1		Concentrate SWE 2		P for diets
		A High	B High	C Low	D High	E Low	
Milk, kg	LSM	36.2 ^a	35.1 ^{ac}	32.3 ^b	35.4 ^{ad}	33.4 ^{bc}	0.0004
	SD	7.8	5.5	5.4	6.6	6.5	***
Milk fat, %	LSM	3.79	3.83	3.96	3.84	3.84	0.43
	SD	0.49	0.46	0.38	0.41	0.59	NS
True milk protein, %	LSM	3.24 ^a	3.35 ^{bc}	3.35 ^{bc}	3.33 ^b	3.38 ^c	<0.0001
	SD	0.24	0.21	0.23	0.20	0.26	***
Milk lactose, %	LSM	4.94	4.95	4.96	4.94	4.97	0.7
	SD	0.14	0.13	0.13	0.15	0.11	NS
Energy-corrected milk, kg	LSM	35.1 ^a	34.6 ^a	32.4 ^b	34.9 ^a	33.0 ^b	0.005
	SD	6.3	4.3	4.6	6.1	5.22	**
Milk fat, g	LSM	1355	1329	1273	1348	1263	0.07
	SD	278	154	193	250	222	NS
Milk protein, g	LSM	1159 ^a	1169 ^a	1075 ^b	1171 ^a	1116 ^a	0.001
	SD	183	158	140	200	166	***
Urea, mg/dl	LSM	29.37 ^a	29.32 ^a	20.43 ^b	32.49 ^c	20.84 ^b	<0.0001
	SD	0.71	0.92	0.51	0.85	0.54	***
SCC, log10, 1000 per ml	LSM	2.125	2.0899	1.9858	2.0144	2.0414	0.8409
	SD	0.4053	0.5021	0.4217	0.4133	0.3804	NS

^{a,b,c,d}Values within a row without common letter differ significantly ($P < 0.05$).

**Significance level; $P < 0.01$.

***Significance level; $P < 0.001$.

total consumed N, without consideration to changes in BW or score. Extremely high efficiencies around 42% were observed with low protein diets. The efficiency was also rather high, around 34%, with the high level diets. According to Aarts et al. (1992), in a cite of van Vuuren and Mejs (1987), maximum 43% of ingested N can be transferred into milk and body yield. Aarts et al. (1992) are of the opinion that the nitrogen efficiency in practice will be 15 to 25%. In our Swedish experimen-

tal herd, the N efficiency has been around 25 to 32%, when feeding after standard recommendations (~19% CP).

Manure

Daily amounts of fresh manure or manure DM percent did not differ significantly between diets. There were significant differences in both total-N and ammo-

Table 7. Average milk quality expressed as content of milk nitrogen fractions in morning milk. Blocks 1 and 3.

		Control	Concentrate SWE 1		Concentrate SWE 2		P for diets
		A High	B High	C Low	D High	E Low	
Total N, %	LSM	0.482 ^a	0.498 ^{ab}	0.504 ^b	0.507 ^b	0.511 ^b	0.0258
	SD	0.033	0.034	0.034	0.030	0.047	*
Soluble N, %	LSM	0.109	0.112	0.1108	0.117	0.113	0.0837
	SD	0.009	0.012	0.013	0.010	0.015	NS
NPN, %	LSM	0.027 ^a	0.028 ^a	0.021 ^b	0.030 ^c	0.023 ^b	<0.0001
	SD	0.003	0.003	0.002	0.003	0.002	***
Casein, %	LSM	2.38 ^a	2.47 ^{ab}	2.53 ^b	2.49 ^b	2.54 ^b	0.0153
	SD	0.22	0.20	0.11	0.22	0.26	*
Whey protein, %	LSM	0.522 ^a	0.535 ^a	0.550 ^{ab}	0.555 ^{ab}	0.578 ^b	0.1241
	SD	0.055	0.080	0.085	0.049	0.091	NS

^{a,b,c}Values within a row without common letter differ significantly ($P < 0.05$).

* $P < 0.05$.

*** $P < 0.001$.

Figure 1. Nitrogen efficiency with different diets.

nium-N in wet manure depending on the content of CP in the diet (Table 8). Especially, diet D showed high levels of nitrogen in manure. The concentrate SWE 2 included linseed cake in contrast to the other concentrate mixtures. The protein level had little influence on organically bound N.

Comparing the production of manure and nitrogen in manure on a yearly basis, excluding the pasture period, clearly demonstrates a lower production of nitrogen with a lower protein content in feed. Especially, the production of ammonia decreases in treatments C and E (Table 9).

Ammonia Release

The results from the estimation of ammonia release from fresh manure are presented in Table 10. The low protein diets C and E gave significantly lower ammonia release compared with the high protein diets ($P < 0.0001$). Even here, a slightly higher level of ammonia ppm was observed for the linseed concentrate, especially between diets E and C ($P = 0.18$).

Economic Comparison

The average daily consumption of the different concentrates is presented in Table 11. The prices of concentrate feeds are given in Table 2. The concentrate in diet A, a commercial concentrate from the local feed supplier, costs 2.38 **SEK** (Swedish crown) per kilogram. The cost of the grain mixture is 1.30 SEK per kilogram. In Figure 2, a relative comparison is made of income over feed costs. Diet C had a lower feed cost per kilogram of milk, but also lower milk yield, which influenced on net profit. The other treatments have nearly same net profit (Figure 2).

It is always difficult to make an economic comparison due to the shifting prices on the world market. From Table 11 it can be concluded that a change in the grain price will reflect in the competitiveness of C and E, due to their high consumption of grain. Figure 2 shows that, at current prices, the diets with Swedish feed ingredients are competitive.

DISCUSSION

According to Tamminga (1992) the nitrogen content in dairy diets should not exceed 30 g of N/kg of DM. This corresponds to a content of CP of 187 g/kg of DM or 18.7% CP. Wu and Satter (2000) investigating high-yielding cows treated with bST, recommended high-yielding cows (~11,000 kg/308 d), a minimum of 17.5% CP including 35 to 37% RUP. Crude protein for bST-treated cows ought to be reduced to 16% after midlactation. The feeding frequency has influence on the ideal CP content in the diet. St-Pierre and Thraen (1999) consider that, with TMR, it is possible to decrease the

Table 8. Daily amounts of manure per cow and the contents of DM, N and $\text{NH}_4\text{-N}$ in manure.

Item		Control	Concentrate SWE 1		Concentrate SWE 2		<i>P</i> for diets
		A High	B High	C Low	D High	E Low	
Fresh manure, kg	LSM	47.4	47.2	44.5	47.4	44.1	0.3512
	SD	5.0	5.9	4.2	6.5	8.1	NS
DM, %	LSM	14.5	14.4	14.1	14.4	14.6	0.9388
	SD	1.5	1.5	1.3	1.9	2.2	NS
Manure DM, kg	LSM	6.8	6.7	6.3	6.7	6.3	0.3277
	SD	0.4	0.8	0.6	0.6	0.7	NS
Total-N, kg/tonne	LSM	6.05 ^a	6.10 ^a	4.89 ^b	6.70 ^c	5.11 ^b	<0.0001
	SD	0.84	0.67	0.55	0.73	0.92	***
$\text{NH}_4\text{-N}$, kg/tonne	LSM	2.06 ^a	2.06 ^a	0.92 ^b	2.44 ^c	0.93 ^b	<0.0001
	SD	0.48	0.41	0.41	0.44	0.35	***
Organic N, kg/tonne ¹	LSM	3.99	4.04	3.94	4.26	4.18	0.1521
	SD	0.43	0.36	0.35	0.49	0.75	NS

^{a,b,c}Values within row without common letter are significantly different ($P < 0.05$).

¹Values calculated as difference between total-N and $\text{NH}_4\text{-N}$.

*** $P < 0.001$.

Table 9. Influence of treatments on the total production of N in manure (300 d, kg/cow).

Treatment	Manure, kg/d	Production of total N, kg	Production of ammonia, kg	Production of organic N, kg
A	47.4	123	42	81
B	47.2	123	47	82
C	44.5	91	17	74
D	47.4	135	49	86
E	44.1	97	18	79

average CP content from 17.7% CP in single TMR to 17.3% CP by splitting the herd in three groups. In the latest issue of NRC (2001), they conclude, based on several protein feeding trials, that increased content of CP in the diet gave increased milk production, but above 19% the increase was not large and the relationship was not strong. NRC (2001) divides the CP into several fractions; metabolizable protein (**MP**), instead of absorbed protein, RDP, and RUP. RUP is not a constant fraction; it varies depending on the outflow rate from rumen or the rate of degradation in the rumen. MP consists of microbe protein + RUP + endogenous protein (**ECP**) (Gustafsson, 2001). The MP is close to AAT in the Nordic protein evaluation system (Madsen, 1985).

In our investigation, CP varied between 13.1 and 17% of DM in the diets. The very low protein levels, especially in diet C, resulted in lower milk yield for diets C and E (Table 6). One explanation of this may be that these treatments had an overall lower feed consumption. The control diet A gave a significantly lower protein content in the milk compared with all other diets. The amount of NPN and the amount of urea were significantly lower in the treatments with lower protein content in the diet (Tables 6 and 7). Furthermore, a higher protein content in the feed ration led to lowered casein content and a tendency to decreased whey protein (Table 7). The Swedish AAT recommendations were fulfilled or exceeded in treatments A, B, and D (45 to 40 g AAT/kg of ECM), but only 37 g of AAT in diets C and E. On the other hand, the higher value of 45 g of AAT in diet A is in accordance with applied practical feeding in Sweden (Lidström, 2001). The PBV value was below recommendations in treatments C and

E, but without seriously decreasing the milk yield (Table 6). An explanation of this is, as pointed out by NRC (2001), that the mixture between protein or, more accurately, protein fractions and the different types of carbohydrates is more important than the total amount of CP in the diet. The linseed cake might explain the higher release of ammonia and nitrogen in manure in diet D. The cake was cold-pressed and not heated, like the rapeseed meal, which might have resulted in a faster degradability in the rumen.

At the same protein level, the diets with Swedish origins functioned as well as the control diet and no significant differences in milk production were observed between diets A, B, and D. In contrast, the very low protein levels in diets C and E resulted in decreased milk yield. In an earlier feeding experiment (Frank and Nilsson, 1998), the comparison of diets with 19, 16, and 14.5% CP did not result in influences on milk production. Other influences on milk protein content and fractions agreed with the results in the present study. The very high nitrogen efficiency (Figure 2) in this experiment is probably connected with the beet fiber in the diets, which gives the rumen microbes a possibility to match the inflow of protein with easily digestible carbohydrates of other types than starch. The carbohydrates in the super-pressed beet pulp are to 50% composed of pectin and hemicelluloses, which are digestible in the rumen to nearly 100%. The cow consumes the beet pulp silage during a longer time compared with concentrates. This ought to result in a more even fermentation in the rumen with improved feed utilization. Furthermore, the protein in beet pulp consists to 97% of true protein as amides and NPN are released during the sugar extraction process (Kelly, 1983). The rumen de-

Table 10. Ammonia release from fresh manure with different diets, ppm in ventilation chamber outlet air.

		Control	Concentrate SWE 1		Concentrate SWE 2		P for diets
		A	B	C	D	E	
Level of CP		High	High	Low	High	Low	
Real CP, %		17.0	16.6	13.1	17.0	13.5	
Ammonia, ppm	LSM	8.39 ^a	8.33 ^a	3.76 ^b	8.87 ^a	4.76 ^b	<0.0001
	SD	1.59	2.41	1.18	2.74	1.40	***

^{a,b}Values within a row without common letter differ significantly ($P < 0.05$).

Table 11. Average daily consumption of feeds in different diets A to E, kg of feed or DM.

	A		B		C		D		E	
	Feed, kg	DM, kg	Feed, kg	DM, kg	Feed, kg	DM, kg	Feed, kg	DM, kg	Feed, kg	DM, kg
Hay	0.99	0.84	0.98	0.84	0.99	0.84	0.98	0.83	0.99	0.84
Silage	20.8	6.19	19.83	5.87	21.88	4.96	24.23	5.76	16.56	4.89
Beet pulp	9.73	2.56	9.48	2.50	17.17	4.52	9.24	2.43	15.53	4.08
Grain	5.57	4.86	4.90	4.25	8.16	7.12	4.06	3.54	7.59	6.58
Control	6.77	5.97								
SWE 1			7.43	6.62	2.50	2.19				
SWE 2							8.28	7.37	2.79	2.49

gradability (EPD) of beet pulp protein is 61%, resulting in a high supply of AAT (Spörndly, 1995). Sugar beet is a popular plant in the south of Sweden, but cannot be grown in central or northern Sweden (Bertilsson et al., 2001). The economic comparison clearly shows that it is possible to compile diets using products of Swedish origin and still be competitive. On the other hand, the situation may quickly change if world market prices alter. The lower daily feed costs with diets C and E may compensate a lower milk production of about 2 kg of ECM per day.

CONCLUSIONS

The urea content of milk and contents of total-N and $\text{NH}_4\text{-N}$ in manure are strongly linked with the protein content in the diet. The NH_3 release from fresh manure can be reduced with lowered protein content in the feed ration. An overfeeding with protein in the diet affects milk quality; hence, more urea is produced. A protein content in the diet around 17% seems to be sufficient, at least under Swedish conditions. As little as 13 to 13.5% CP in the diet seems to be too low, resulting in decreased milk yield. In the south of Sweden, at least, it is possible to have an intensive milk production without any major imports of feedstuffs.

Figure 2. Income over feed costs, relative values.

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