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Influence of lucerne/fescue silage mixtures on milk production of early-lactation Holstein cows*

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ABSTRACT

Our objective was to determine the effects of various mixtures of lucerne (*Medicago sativa*, L.) and tall fescue (*Festuca arundinacea* Schreb.) silages, fed to provide 1.1% of body weight as forage-neutral detergent fibre (NDF) in the diet, on milk production and composition, and associated digestion kinetic and ruminal parameters. NDF was provided from 1:0 lucerne: fescue, 0.67:0.33 lucerne:fesuce, 0.33:0.67 lucerne:fescue, or 0:1 lucerne:fescue. Diets were fed to five cows in an incomplete Latin square design (two periods). Dry matter intake increased as portion of concentrate and fescue in the diet increased. This resulted in higher milk production ($P<0.05$) for cow consuming diets with increasing fescue forage in the diet (32.3, 34.5, 38.9, and 40.5 kg d^{-1}, respectively). Milk protein increased with decreased lucerne in the diet. Milk urea nitrogen was higher for cows fed the lucerne forage diet due to its high protein solubility and high inclusion in the diet. Lower forage to concentrate ratios resulted in less indigestible fibre and higher non-structural carbohydrate in the tall fescue diet and accounted for higher milk production.

KEY WORDS: cows, silages, milk production, milk composition

INTRODUCTION

Many dairy farms have land that is poorly suited to growing lucerne because of low pH or poorly drained soils (Cherney et al., 1998b). Grasses will have

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advantages over legumes in these areas because they can use nitrogen from manure, support vehicle traffic and tolerate marginal soils. Perennial grass can also remove over twice the nitrogen/acre compared to maize (Kanneganti and Klausner, 1994). Many dairy producers have forage stands with a mixture of lucerne and grass.

The agronomic yield potential of tall fescue in New York (USA) was more than 20% higher than orchardgrass (*Dactylis glomerata*, L.) in a New York study (Cherney et al., 2002). There are variable opinions about its quality for dairy cattle, in part due to the major problems associated with all old endophyte-infected varieties (Strahan et al., 1987). Most studies using fescue in dairy cattle diets in the past compared the feeding of endophyte-free tall fescue versus endophyte-infected tall fescue varieties. In another study, cows fed fescue had higher milk production than those fed orchardgrass, despite similar chemical composition (Cherney et al., 1998a).

Balancing rations for carbohydrates should ensure that energy density of the ration adequately meets requirements for milk yield and that there is enough fibre in the diet to provide for proper ruminal fermentation (Mertens, 1992). Because neutral-detergent fibre (NDF) and non-fibrous carbohydrates (NFC) are inversely related, balancing for one usually balances the other in a ration (Mertens, 1992). Balancing for maximum NDF in the diet is designed to allow most cows in a group to attain their potential with optimal ruminal fills (Mertens, 1992). In many cases, it will maximize the use of homegrown feeds, which can have a favourable impact on farm nutrient balance (Wang et al., 2000).

There are a number of studies, however, suggesting that NDF quality influences voluntary intake and resulting milk production (Robinson and McQueen, 1997; Jonker et al., 2002). Robinson and McQueen (1997) reported that cows fed a diet high in NDF digestibility had higher dry matter intake and milk production than those cows fed a lower digestibility diet; a lower quality lucerne silage was substituted for high-quality lucerne silage and a combination of ryegrass and timothy silages replaced barley silage to achieve lower digestibility diets. Cherney et al. (1998a) also reported that high-digestibility forage (early-cut orchardgrass) had higher dry matter intake and milk production than a low-digestibility forage (late-cut orchardgrass). There is very little information, however, on how cows will perform as grass silage, particularly fescue, replaces a portion of the lucerne silage.

MATERIAL AND METHODS

A feeding trial using lactating Holstein cows (581±64.8 kg body weight; 2.1±1.02 lactations, 129±16.5 days in milk producing 41.5±6.5 kg d^{-1} milk at trial initiation) was conducted. The design was an incomplete 4x4 Latin square (2 periods) replicated five times for a total of 20 cows. Diets were balanced to meet National Research Council (NRC, 1989) minimum requirements for crude protein, energy, and minerals. Forage was included at 1.1% of BW as forage NDF. Forage consisted of 1:0 lucerne:fescue, 0.67:0.33 lucerne:fescue, 0.33:0.67 lucerne: fescue or 0:1 lucerne:fescue. Because of the constraint on the amount and type of forage used, it was impossible to just meet requirements for protein in the predominantly lucerne forage-based diets. Diets were in the range of what is considered a normal diet for a high producing cow in the USA (Table 1; NRC, 1989). Lucerne and tall fescue silages were considered good quality (Table 2).

TABLE 1

Diet formulations and composition, g kg^{-1}, dry matter basis [1]

Constituent	Forage ratio			
	1:0 luc:fes	0.67:0.33 luc:fes	0.33:0.67 luc:fes	0:1 luc:fes
Forage:concentrate	84:16	70:30	59:41	51:49
Lucerne silage	841	467	195	0
Tall fescue silage	0	231	394	514
Maize meal	109	203	257	306
Soyabean meal	0	0	0	58
Homer meal[2]	19	68	116	78
Lactose	19	19	19	19
Limestone	0	0	8	14
Trace mineral salt[3]	12	12	12	12
Forage-NDF, kg d^{-1} [4]	6.7	6.7	6.7	6.7
Ration CP[5]	209	190	174	185
Soluble-CP, g kg^{-1} of CP[5]	620	500	380	410
Ration NDF[6]	283^{a}	303^{b}	316^{c}	313^{bc}
Ration ADF[6]	206^{c}	191^{b}	176^{a}	181^{a}
Ration lignin[6]	41^{c}	30^{b}	22^{a}	20^{a}
Ration NFC[5]	337	353	406	388
Ration NEL, mcal kg^{-1} [5]	1.61	1.65	1.65	1.61

[1] diet formulation prepared using Cornell Net Carbohydrate and Protein System (Fox et al., 2000)

[2] Homer meal is a commercial extracted soyabean meal protein supplement with, %: 47.5 crude protein, 7.9 fat, 6.6 fibre, 9 acid-detergent fibre, 22.6 neutral-detergent fibre, 60 by-pass protein, 7 soluble protein on a dry matter basis

[3] chemical composition of mineral mix is as follows, %: ash 100, Ca 10-14, P 0, Mg 8, K 1, Na 13-15, Cl 20, S 8; mg kg^{-1}: Co 57, Cu 800, Fe 2000, I 90, Mn 5400, Zn 6200, Se 20; KIU kg^{-1}: vit. A 551, vit. D 60, vit. E 1350 on a DM basis

[4] forage-NDF expressed as % of body weight = 1.1%

[5] determined by DHI Forage Testing Laboratory, Ithaca, NY

[6] determined for each cow, sample composite of 7 days (n=5/treatment)

^{abc} $P<0.05$

TABLE 2

Chemical composition[1] of forages, g kg^{-1}

Constituent	Lucerne silage	Tall fescue silage
Dry matter	301	340
Crude protein	232	165
Soluble CP, g kg^{-1} of CP	690	720
ADICP	8	7
NDICP	19	17
ADF	276	322
NDF	342	561
Lignin	64	66
NFC	277	150
Crude fat	38	49
NEL, Mcal kg^{-1} [1,2]	1.48	1.28

[1] ADICP=acid detergent insoluble CP, NDICP=neutral detergent insoluble CP, ADF=acid detergent fibre, NDF=neutral detergent fibre, NFC=non-fibrous carbohydrates, NEL=net energy for lactation
[2] net energy for lactation is by Van Soest variable discount method (Van Soest and Fox, 1992)

Cows were housed in individual tie stalls throughout the experiment and had free access to water throughout the trial. Cows were offered a total mixed ration for *ad libitum* intake once daily (10.00 h) to allow for 10% orts. Cows were randomly assigned to treatment. Feed offered and refusals were recorded daily. Feed offered was sampled daily and DM determined. The study had Cornell University Institutional Animal Care and Use Committee approval. This committee ensures that all animals were used in compliance with federal, state and local laws and regulations involving animal care and use, and that the study was conducted in such a manner as to avoid unnecessary animal discomfort.

Cows were milked three times daily (08.00, 16.00 and 24.00 h). Milk was recorded daily, sampled at all milkings and composited for each milking during the week of data collection. Samples were preserved with 2-bromo-2-nitropropane-1, 3 diol. Samples were analyzed for fat, total protein, milk urea nitrogen (MUN), and lactose at the New York DHI milk testing laboratory (Ithaca, NY; infrared analysis: Foss 605B Milko-Scan; Floss Electric, Hillelrod, Denmark). Diet and dietary ingredients were sampled weekly throughout the trial. Dry matter (60°C, 48 h) was determined weekly on these samples and TMRs were adjusted as necessary.

Diet and refusals were analyzed for crude protein (CP), NDF, acid detergent fibre (ADF), and sulphuric acid lignin. Crude protein was estimated by Kjeldahl N x 6.25. NDF, ADF, and sulphuric acid lignin were analyzed according to Van Soest et al. (1991).

One cow on each treatment was a ruminally-fistulated animal. Forage samples (5 g of 4-mm ground material) were incubated in nylon bags to determine rate of digestion according to procedures outlined by Nocek (1988) as influenced by forage type and diet. Nine incubation times, 0, 6,12, 18, 24, 30, 36, 48, and 72 h, were used. Ruminal pH was determined 4 h after initial feeding for three days each period. Samples were also collected for volatile fatty acid (VFA) analysis.

The statistical model included period and diet as dependent variables. Animal was a random variable in the model. The interaction term was period x diet. Production data were analyzed to determine effects of diet using the general linear model procedure of SAS (1989). Differences among means were evaluated using F tests. Significance was P<0.05 unless otherwise stated.

RESULTS

Milk production increased linearly with increasing fescue/concentrate in the diet, as did dry matter intake (Table 3). There was also a linear increase in forage NDF intake. Cows fed fescue diets had higher milk protein than those on pure lucerne or 0.67 : 0.33 lucerne:fescue. Milk urea nitrogen was highest for cows fed the 1 : 0 lucerne:fescue diet (Table 3). Milk fat and milk lactose were unaffected by diet.

TABLE 3

Influence of diet on milk production, body weight, intake and milk composition

Constituent	Forage ratio[1] 1:0 luc:fes	0.67:0.33 luc:fes	0.33:0.67 luc:fes	0:1 luc:fes	Effect[2] linear	quadratic
Milk, kg d^{-1}	32.3[a]	34.5[b]	38.9[c]	40.5[c]	**	NS
Body weight, kg	591[a]	590[a]	589[a]	600[a]	NS	NS
DM intake, kg d^{-1}	20.5[a]	20.8[a]	23.4[b]	24.6[b]	**	NS
DM intake, % of BW[3]	3.47[a]	3.51[a]	3.96[b]	4.10[b]	**	NS
F-NDF intake, % of BW	1.00[a]	1.02[a]	1.14[b]	1.17[b]	**	NS
Milk fat, g kg^{-1}	36.6[a]	35.1[a]	37.1[a]	33.3[a]	NS	NS
Milk true protein, g kg^{-1}	27.0[a]	27.4[ab]	28.1[ab]	29.0[b]	**	NS
Milk lactose, g kg^{-1}	47.3[a]	47.8[a]	48.0[a]	48.0[a]	NS	NS
Milk urea N, mg/dl	16.4[a]	13.7[b]	13.0[b]	13.1[b]	**	*

[1] forage is included in diet to provide 1.1% of cow body weight as forage NDF. Remainder of diet is maize, soyabean meal and minerals

[2] linear, quadratic effect of treatment (**=P<0.01, *=P<0.05, NS=not significant at P<0.05 level of probability)

[3] BW=body weight, F-NDF intake=intake of neutral detergent fibre from forage

[a,b,c] P<0.05

Ruminal pH was higher in cows offered pure lucerne or 0.33 : 0.67 lucerne:fescue than those offered more fescue-based TMR (Table 4). Major ruminal volatile fatty acids (acetate, propionate, and butyrate) did not differ among diets, but there was a trend towards lower acetate and higher propionate in the diet containing all lucerne forage. This resulted in a lower ruminal molar acetate:propionate for cows receiving all lucerne forage in their diets. Total acid concentration did not differ among diets.

TABLE 4

Influence of diet on ruminal pH and volatile fatty acids

Constituent	Forage ratio[1]				Effect[2]	
	1:0 luc:fes	0.67:0.33 luc:fes	0.33:0.67 luc:fes	0:1 luc:fes	linear	quadratic
pH	6.47[a]	6.25[a]	5.86[b]	5.72[b]	**	NS
Acetate:propionate ratio	2.58[a]	3.18[b]	3.40[b]	3.29[b]	**	NS
Acetate, mmol/l	72.8[a]	76.3[a]	76.1[a]	76.3[a]	NS	NS
Propionate, mmol/l	28.1[a]	24.9[a]	23.8[a]	24.1[a]	NS	NS
Butyrate, mmol/l	15.7[a]	14.2[a]	14.2[a]	15.8[a]	NS	NS
Isobutyrate, mmol/l	1.1[a]	1.7[b]	1.4[ab]	1.2[ab]	NS	*
Total acids, mmol/l[3]	117.7[a]	117.2[a]	115.6[a]	117.3[a]	NS	NS

[1] forage is included in diet to provide 1.1% of cow body weight as forage NDF. Remainder of diet is maize, soyabean meal and minerals

[2] linear, quadratic effect of treatment (**=$P<0.01$, *=$P<0.05$, NS=not significant at $P<0.05$ level of probability)

[3] total acids=acetate + propionate + butyrate + lactate + iso-butyrate, mmol concentrations

[ab] $P<0.05$

Low fibre in the lucerne (Table 2) limited the amount of concentrate needed in the all lucerne forage diet to meet requirements, resulting in a high forage to concentrate ratio (Table 1). *In situ* extent of fibre digestion was higher for tall fescue than lucerne, as was the potentially digestible fibre (Figure 1). Indigestible fibre residue was lower in tall fescue than lucerne (Figure 1). Rate of digestion was higher for lucerne (0.076 h^{-1}) than fescue (0.045 h^{-1}). While the forages differed in digestion kinetic parameters, diet did not influence rate, extent, potentially digestible fibre or indigestible fibre residue of these forages.

DISCUSSION

Concentrates typically increase milk production by allowing for higher dry matter intake (Weiss, 1995; Robinson and McQueen, 1997), consistent with results in our study. Despite similar NDF contents, our diets differed in the amount of lignin and resulting indigestible fibre in the diets. Miller et al. (1990) reported cows fed more fermentable fibre had higher dry matter intake. Robinson and McQueen (1997)

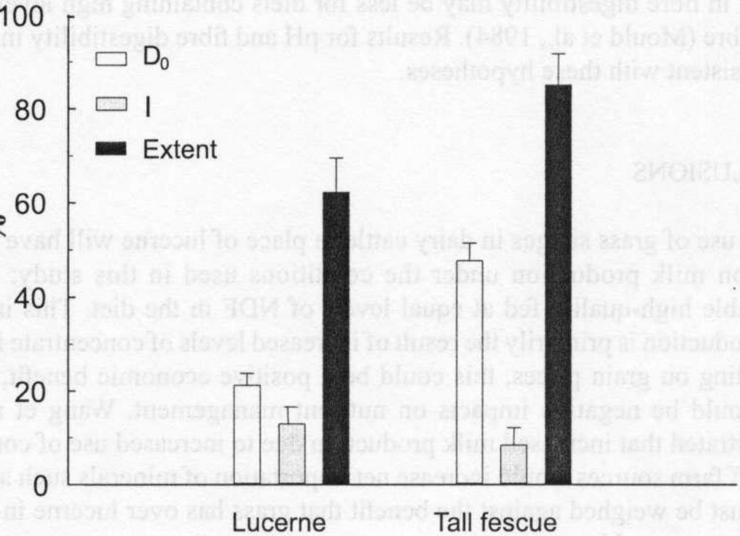

Figure 1. Influence of forage type (lucerne or tall fescue) on potentially digestible fibre as a percent of dry matter (D0), indigestible fibre as a percent of dry matter (I) and extent of fibre digestion as a percent of initial fibre (Extent)

suggested that demonstrating an intake response due to fermentable fibre requires relatively high milk production, and that milk production be limited by dry matter intake. Our data fits with these observations and explanations. As a result of the high inclusion rate of lucerne, non fibrous carbohydrate (NFC) concentration was low in the all lucerne forage diet, which may have further limited production. The inclusion of NFC ranging from 350 to 420 g kg^{-1} of dietary dry matter is often used to increase energy density of diets (Lykos et al., 1997).

No differences in milk composition due to forage silage type (grass or lucerne) were observed in several studies (Weiss and Shockey, 1991; Orozco-Hernandez et al., 1997). Our results for milk fat and milk lactose are consistent with these results. Protein solubility generally decreased with decreasing lucerne in the diets (Table 1). It is likely that protein efficiency improved as this occurred (Van Soest, 1994), resulting in lower milk urea nitrogen and/or higher milk protein.

Lucerne has higher buffering capacity than perennial grasses (McBurney et al., 1983), resulting in linearly higher pH with increasing proportion of lucerne in the diet. A pH lower than 6.2 has been reported to inhibit fibre digestion (Grant and Mertens, 1992; Pitt et al., 1996), but high rate of digestion of high quality forages has been reported with a mean ruminal pH of 5.8 to 6.2 (Kolver et al., 1998), as in our study. De Veth and Kolver (2001) reported that digestion was insensitive to pH between 5.8 and 6.6, but that a large reduction occurred when pH was below 5.4. They attributed this insensitivity to a lack of lactate production, and that reduction in fibre digestibility may be less for diets containing high levels of digestible fibre (Mould et al., 1984). Results for pH and fibre digestibility in our study are consistent with these hypotheses.

CONCLUSIONS

The use of grass silages in dairy cattle in place of lucerne will have a positive effect on milk production under the conditions used in this study: forage of reasonable high-quality fed at equal levels of NDF in the diet. This increase in milk production is primarily the result of increased levels of concentrate in the diet. Depending on grain prices, this could be a positive economic benefit, however, there could be negative impacts on nutrient management. Wang et al. (2000) demonstrated that increased milk production due to increased use of concentrates from off farm sources would increase net importation of minerals such as N and P. This must be weighed against the benefit that grass has over lucerne in its ability to utilize manure N.

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STRESZCZENIE

Wpływ podawania kiszonki z lucerny i kostrzewy trzcinowej na produkcję mleka przez krowy holsztyńskie we wczesnym okresie laktacji

Celem badań było określenie wpływu skarmiania kiszonek o różnym udziale lucerny i kostrzewy, na produkcję i skład mleka oraz na kinetykę trawienia i wybrane wskaźniki żwacza. Kiszonki podawano w takiej ilości, aby udział NDF w dawce stanowił 1,1% masy ciała. Przygotowano kiszonki o następującym udziale lucerny i kostrzewy: 1:0; 0,67:0,33; 0,33:0,67 oraz 0:1; odpowiednio. Doświadczenie, o układzie niekompletnego kwadratu łacińskiego (dwa okresy) przeprowadzono na 5 krowach.

Pobranie suchej masy zwiększało się wraz ze zwiększeniem udziału paszy treściwej i kostrzewy w dawce. W miarę zwiększania dawki kostrzewy wzrastała ($P<0,05$) produkcja mleka i wynosiła 32,3; 34,5; 38,9 i 40,5 kg d^{-1}, odpowiednio. Zawartość białka w mleku zwiększała się wraz z malejącą ilością lucerny w dawce. Ilość N mocznikowego w mleku była większa u krów otrzymujących kiszonkę z lucerny, co spowodowane było większą rozpuszczalnością białka lucerny i dużym jej udziałem w dawce. Przy niższym stosunku kiszonki do paszy treściwej ilość niestrawnego włókna była mniejsza, a węglowodanów niestrukturalnych większa w dawkach z kostrzewą trzcinową, co stwarzało warunki do wyższej produkcji mleka.