Influence of pasture allowance on the composition and cheese-yielding potential of milk.

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Abstract

Effects of pasture allowance on the yield, composition and cheese-yielding potential of milk were investigated using 48 Friesian cows in cross-over experiments during spring (~60 days after calving) and summer (~180 days after calving). All cows were subjected to two nutritional treatments: *ad lib.* grazing (pasture allowance >45 kg DM/cow/day) and restricted grazing (16–18 kg DM/cow/day). Milk samples were collected from each cow on the final day of each treatment period and analysed for a range of components. Pasture dry matter intakes (DMI) during treatment periods were determined using the n-alkane technique. Increasing pasture allowance resulted in increased DMI. Cows grazing *ad lib.* had higher milk yields, concentrations of protein (spring only), casein, whey protein (spring only), casein:whey protein ratio (summer only), α-casein, β-casein and urea, but lower concentrations of serum albumin and immunoglobulin, than cows grazing a restricted pasture allowance. Nutritional effects on milk composition were greatest in spring, at which time theoretical Cheddar cheese yields were greater for milk from cows grazing *ad lib.* than restricted cows. Concentrations of some milk components were correlated with DMI of cows. These results provide evidence that on-farm management practices can affect milk composition and the potential yield of dairy products. Maintaining an adequate pasture allowance for dairy cows is important not only to maximise milk production, but also to optimise the manufacturing potential of milk.

Keywords: casein, cheese, milk, pasture allowance, protein

Introduction

Milk composition has an important influence on the yield and quality of dairy products (Dalgleish 1992). As the New Zealand dairy industry becomes more aware of this fact, research is focusing on how milk composition can be manipulated on-farm to maximise processability before it reaches the factory. Nutrition is one on-farm influence which can affect milk composition (Murphy & O'Mara 1993).

The New Zealand dairy industry relies on grazed pasture as almost the sole source of feed. For this reason, any fluctuations in the availability and quality of pasture will alter the cows' plane of nutrition, and therefore, presumably, the volume and composition of milk produced. The study reported here was designed to investigate the effects of pasture allowance on milk composition, and the potential of that milk for cheese manufacture.

Materials and methods

Animals, treatments and design

Forty-eight multiparous Friesian cows were subjected to two nutritional treatments in cross-over experiments during spring (October/November; an average of 60 days after calving) and summer (February/March, an average of 180 days after calving). Treatments were *ad lib.* grazing (pasture allowance >45 kg DM/cow/day) and restricted grazing (pasture allowance 16–18 kg DM/cow/day). Cows grazed together *ad lib.* for 10 days before the experiment. The cows were then divided into two groups, one of which was subjected to each nutritional treatment for 8 days. Following this, all cows again grazed together *ad lib.* for 14 days, and thereafter cows received the alternative treatment for a further 8 days. Cows grazed similar ryegrass–white clover pasture on adjacent paddocks throughout the experiment. Pre-grazing pasture mass was determined using a rising plate meter (L'Huillier & Thomson 1988) and approximated 4000 and 3300 kgDM/ha in spring and summer, respectively. Pasture restriction was achieved by reducing the area of pasture available to the cows. Pasture intakes of individual cows were determined using the n-alkane technique (Dove & Mayes 1991).

Sampling and analyses

Milk yields were recorded on the final day of each treatment period, and samples of the daily milk were collected from each cow using in-line milk meters (Tru-test Ltd., Auckland). Samples were analysed for fat, protein, lactose, somatic cell count (SCC), nitrogen fractions, immunoglobulin G (Ig G) and bovine serum albumin (BSA), using the techniques outlined by Auldist *et al.* (1998). Proportions of (α, β, and κ-casein were measured using sodium dodecyl sulfate polyacrylamide gel electrophoresis followed by densitometry (Hill 1993).

Theoretical Cheddar cheese yields were calculated using the following formula (Van Slykes theoretical cheese yield formula; Lou & Ng-Kwai-Hang 1992), assuming a cheese moisture content of 34%:

Cheddar cheese yield = ((0.93 × fat%) + (casein%-0.l))*1.09/(1-cheese moisture%/100)

Statistical analyses

Data were analysed in SAS (SAS Version 6; SAS Institute Inc., NC, USA) using the restricted maximum likelihood method of the mixed-model procedure. Analyses were conducted for each season, treating cow and period as random effects and pasture allowance as a fixed effect. Data from cows with SCC exceeding 400 000 cells/ml were omitted from the analyses to avoid the confounding effects of mastitis on milk composition (Auldist & Hubble 1998).

Results

Estimated pasture allowances of >45 and 16–18 kg DM/cow/day resulted in mean DMI of 15.9 and 11.0 kg DM/cow/day for *ad lib.* and restricted cows respectively in spring and 11.0 and 6.6 kg DM/cow/day for *ad lib.* and restricted cows respectively in summer.

Cows grazing *ad lib.* had higher milk yields, concentrations of protein (spring only), casein, whey protein (spring only), casein:whey protein ratio (summer only), α-casein, β-casein and urea, but lower concen-trations of BSA and Ig G, than cows grazing a restricted pasture allowance. Concentrations of κ-casein were greater in milk from *ad lib.* cows during spring, but greater in restricted cows during summer (Table 1).

In both treatment periods of at least one experiment, pasture DMI was correlated with milk yield and concentrations of protein, casein, α-casein, BSA, Ig G and urea (Table 2).

Discussion

Some previous experiments investigating nutritional effects on milk yield and composition in grazing cows have failed to separate the effects of feed type from the effects of feeding level (Kefford *et al.* 1995; Mackle *et al.* 1998). The current experiment had the aim of investigating the effects of pasture availability on milk yield and composition, and so the type of feed (i.e., pasture) was held constant. The observed effects were therefore primarily due to alterations in feeding level, although minor and potentially confounding effects of pasture selection by cows grazing *ad lib.* are nevertheless acknowledged.

Increasing the pasture allowance was expected to increase pasture intake (Poppi *et al.* 1987), and this was clearly demonstrated using the n-alkane technique. In turn, the higher DMI increased concentrations of total protein and total casein (Table 1), as was also found by O'Brien *et al.* (1997). The increased energy intake would have spared amino acids from gluco-neogenesis, thus increasing the supply available for milk protein synthesis. Concentrations of the individual caseins similarly increased when pasture allowance was increased, again probably because of a greater supply of amino acids since all caseins are synthesised within the mammary gland. Conversely, concentrations of proteins from the blood (BSA and Ig G), which are less useful for the manufacture of most products, increased in milk during underfeeding. Gray & Mackenzie (1987) reported similar effects of pasture allowance on serum proteins, which they attributed at least partly to declining milk volumes. It is possible also that increased concentrations of serum proteins in milk during restricted feeding may indicate increased permeability of the mammary epithelia at that time (Stelwagen *et al.* 1994). Whatever the cause, the results demonstrate that the effects of nutrition can be different for the different milk proteins.

The amount of cheese yielded per kilogram of milk is an important determinant of the profitability of cheese-making. Cheese-yielding capacity of milk is affected by milk composition; the amount of cheese per kg milk increases as the concentrations of fat and protein in milk increases (Lou & Ng-Kwai-Hang 1992). The most important milk protein for manufacturing purposes is casein, particularly but not exclusively for cheese manufacture. It is primarily casein, together with fat, that is incorporated into the curd during cheese-making. For this reason, the Van Slyke formula for predicting cheese yield from milk composition is based around the concentrations of these parameters in the cheesemilk. In the current experiment, theoretical cheese yields in spring were 5% higher for *ad lib.* cows than for restricted cows, owing to the higher concentrations of casein. These differences in theoretical Cheddar cheese yield were similar to those for moisture-adjusted Mozzarella cheese yield reported by Guinee *et al.* (1998), in an experiment in which cheese was actually made from milk from cows grazing different pasture allowances. In summer, level of feeding had no effect on theoretical cheese yields, possibly because the trend for decreased fat concentration in the *ad lib.* cows offset the increase

Table 1 Effect of a high and low pasture allowance on milk composition and theoretical cheese yield in spring (~60 days after calving) and summer (~180 days after calving).

	Spring			Summer		
	Ad lib.	Restricted	SED	*Ad lib.*	Restricted	SED
Pasture allowance	45	18	-	50	18	-
Milk yield	20.3	15.6**	0.48	13.4	8.4 **	0.25
Fat (g/kg)	43.8	42.6	0.64	50.2	51.4	0.85
Protein (g/kg)	33.2	30.2**	0.21	33.9	33.0	0.44
Lactose (g/kg)	49.9	49.7	0.19	49.2	48.4*	0.16
Casein (g/kg)	27.5	25.0**	0.21	27.7	26.6**	0.35
α-casein (g/kg)	12.7	11.3**	0.23	12.9	12.2**	0.19
β-casein (g/kg)	11.4	10.7**	0.15	11.8	11.3**	0.23
κ-casein (g/kg)	2.81	2.51**	0.06	2.79	2.95*	0.06
Whey (g/kg)	5.7	5.2 **	0.10	6.2	6.4	0.12
Serum albumin (mg/1)	208	280**	7.3	233	387**	8.9
Immunoglobulin G (mg/1)	588	622**	11.7	558	731**	19.7
Casein:whey protein	5.0	5.0	0.13	4.6	4.2**	0.07
Urea (mM)	5.11	4.56**	0.11	6.41	5.29**	0.10
Cheese yield (kg/100kg milk)†	11.1	10.5**	0.11	12.1	12.1	0.18

† Theoretical cheese yield calculated using a modification of Van Slykes theoretical cheese yield formula (Lou & Ng-Kwai-Hang, 1992).

in casein concentration. These results highlight the importance of maintaining pasture intake, at least during spring, to optimise the yield of casein-derived dairy products such as cheese and caseinate.

The magnitude of the effects of nutrition on milk yield and composition was dependent on time of year, with effects generally being greatest in spring (Table 1). This was also reported by Petch *et al.* (1997) and Mackle *et al.* (1998). Presumably, this interaction between the effects of season and nutrition was due to other factors which change during the season and which could affect milk yield and composition. Such factors include cow energy requirements, the capacity of the cow to ingest sufficient dry matter to meet requirements, physiological factors associated with stage of lactation, and pasture composition.

Some of the factors noted above were probably responsible for the differences in milk composition between spring and summer (Table 1). Seasonal variation in milk composition has been addressed previously (O'Keeffe 1984; Kefford *et al.* 1995; Lucey 1996; Auldist *et al.* 1998) and is not within the scope of this paper. Nevertheless, it is noteworthy that theoretical cheese yields were greater during summer than spring because of the higher casein and fat concentrations. This must be tempered, however, by reduced milk yields and potential product problems associated with low casein:whey ratios at this time (Lucey 1996).

The correlations between DMI and concentrations of milk components in individual cows (Table 2) were consistent with the effects of DMI on mean milk composition outlined above (Table 1). Nevertheless, the variation in the strength and significance of the correlations indicates that DMI was not always a reliable predictor of milk yield, composition or manufacturing potential.

Table 2 Correlations† (×100) between pasture dry matter intake (DMI) and concentrations of milk components in spring and summer.

	Spring		Summer	
	Period 1	Period 2	Period 3	Period 4
Milk yield	58*	60*	78*	81*
Protein	61*	44*	22	21
Casein	55*	44*	27	30*
Whey	49*	17	-2	-13
α-casein	35*	42*	22	21
κ-casein	42*	21	-17	-3
Albumin	-43*	-55*	-71*	-66*
Ig G	-13	-12	-40*	-51*
Urea	48*	27	39*	69*

* $P<0.05$

† Data presented only for components significantly correlated with DMI in at least one period.

In conclusion, these results provide evidence that on-farm management practices can affect milk composition and hence the potential yield of cheese. A short-term decline in DMI resulting from a reduction in pasture allowance affected concentrations of milk components in different ways, but the extent of these changes was dependent on the time of year. In particular, maintaining an adequate pasture allowance for dairy cows is important not only to maximise milk production, but also to optimise concentrations of casein and therefore the yield of casein-derived products such as cheese. This will be important if manufacturing companies begin to pay for milk based on casein content instead of total protein content.

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