Effect of altering the daily herbage allowance in mid lactation on the composition and processing characteristics of bovine milk

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Milk production in Ireland, New Zealand and Australia is seasonal, with the majority of cows calving in spring. This pattern of production makes the maximum use of grazed grass, and in Ireland > 80% of total milk for manufacturing is produced between April and November inclusive. Such a seasonal pattern of production results in a large variation in the gross composition of milk due to stage of lactation effects (Phelan *et al*. 1982). Some studies have investigated the relationship between milk composition and its processing characteristics (O'Keeffe *et al*. 1982; Grandison *et al*. 1984); however, in these studies the effects of diet and lactation stage were not segregated. Kefford *et al*. (1995) attempted to segregate the effects of diet and stage of lactation and concluded that diet quality (type and quantity) had a larger effect on Cheddar cheese quality than the stage of lactation.

The nutritive value of the diet of cows fed on grazed grass can change owing to changes in grass supply or quality. In the current study, changes in grass supply were achieved by altering the daily herbage allowance (DHA) to the herds. The objective of the current study was to investigate the effect of varying the DHA in the range 16–24 kg grass dry matter (DM), which is typical of the variation in pasture allowance in Ireland in mid lactation, on milk composition and its processing characteristics.

MATERIALS AND METHODS

Design and treatments

The experiment was a randomized block design with three groups of cows each receiving one of three DHA. A total of 36 cows from the Institute's Friesian herd were blocked into groups of three on the basis of calving date, milk yield and live weight, giving a total of 12 blocks. Cows from each block were assigned at random to one of the three diet treatments for a 17 week period. The DHA offered in the three diet treatments were 16, 20 or 24 kg grass DM/cow, i.e. DHA 16, DHA 20 or DHA 24. The specified quantity of grass was given each day by adjusting the grazing area based on herbage mass > 40 mm. Since different post-grazing sward heights resulted from the different daily allowances, all areas were topped to the post-grazing height of the 16 kg/d treatment to ensure no difference in grass quality at subsequent grazings.

Cows

The cows were of Friesian–Holstein breed with an average relative breeding index (RBI 95) of 107 (range 19–121). Cows were on average 66 d (range 27–108) into lactation at the start of the experiment. Treatments DHA 16, 20 and 24 had five cows each with κ-casein AA milk and six, five and four cows respectively with κ-casein AB milk. The three treatments also had respectively one, three and five cows with β-lactoglobulin AA variant, one, three and two with β-lactoglobulin BB variant, and nine, four and two with the AB variant. Genetic variation was unknown for six cows.

Measurements and sampling

Milk yields of individual cows were measured at the morning and evening milkings on 5 d each week and individual samples for measurement of gross milk composition (fat, protein and lactose) were taken at four consecutive milkings weekly. Additionally, milks from individual cows were collected at 4 weekly intervals for detailed compositional analysis and measurement of processing characteristics. Milk from each cow was collected directly from the milking jar at the evening milking, stored overnight at 4 °C and then combined with the subsequent morning's milk sample in proportions according to yield, and the composite analysed. Cows were on average 88 and 177 d into lactation at the first and final samplings.

Milk analysis

Composition. Milk fat, protein and lactose concentrations were measured by automated i.r. analysis using a Milkoscan 203 (Foss Electric, DK-3400 Hillerød, Denmark). Milks were analysed for total protein (International Dairy Federation, 1993), and non-protein N and whey protein as described by Guinee *et al*. (1995). The free fatty acid (FFA) level of milk was determined as described by the Bureau of Dairy Industries (International Dairy Federation, 1991). The total calcium and phosphorus contents of milk were determined according to International Dairy Federation (1992) and (1990) respectively, on a filtrate, after treatment with trichloroacetic acid (120 g/l). Milk somatic cell count (SCC) was measured using a Bentley Somacount 300 somatic cell counter (AgriYork 400 Ltd, York YO4 2QW, UK) after calibration and standardization according to the procedures set out in International Dairy Federation (1984). Milk pH was measured using a Radiometer PHM 82 pH meter fitted with a combination glass reference electrode (GK 2401C; Radiometer, DK-2400 Copenhagen, Denmark).

Rennet coagulation properties. The rennet coagulation characteristics of the milks were determined using a Formagraph (Type 11700, Foss Electric) as described by McMahon & Brown (1982). These properties were measured at the natural pH of milk and after adjustment to pH 6·6. The milk was heated to 31 °C, equilibrated for 20 min and chymosin (double strength Chymax; Pfizer Inc., Milwaukee, WI 53214-4298, USA), diluted 1:100 with deionized water, was added at a rate of 77 μl/10 ml. The following rennet coagulation properties were measured: rennet coagulation time in min and curd firmness at 60 min in mm of amplitude.

Ethanol stability. Ethanol stability of milks was determined according to White & Davies (1958). The results were expressed as the strength of the highest ethanol solution (%) at which coagulation did not occur.

Statistical analysis

Measurements from the individual cows were analysed using the SAS statistical package (SAS, 1985). There were fourteen values over time for yields of milk, fat, protein and lactose and concentrations of fat and lactose. There were four values over time for total milk protein and protein fraction concentrations, ethanol stability, renneting properties, FFA, calcium and phosphorus contents and SCC. In each situation the values were averaged to give a mean value for each measure during the experimental period and statistical analyses were performed on the mean values with the cow as the replicate. Milk yield and gross composition were analysed using the GLM (General Linear Model) procedure removing treatment and block effects and using milk yield and gross composition from the immediate pre-experimental week, lactation number and calving day as covariates. Milk protein and its fractions, ethanol stability, renneting properties, FFA, calcium, phosphorus and SCC were analysed using the GLM procedure taking out treatment and block effects and using lactation number and calving day as covariates. The significance of differences between treatment means was determined using Student's t test. The following model was used to estimate the effects of treatments.

$$Y_{ij} = \mu + \tau_i + \beta_j + \lambda\kappa_{ij} + \gamma\phi_{ij} + \alpha\delta_{ij} + \epsilon_{ij},$$

where Y_{ij} is the response for the ith treatment, jth block, μ is a constant, τ_i the effect of the ith treatment, β_j the effect of the jth block, λ the linear regression coefficient measuring the effect of the pre-experimental variable κ_{ij}, γ the linear regression coefficient measuring the effect of calving day ϕ_{ij}, α the linear regression coefficient measuring the effect of lactation number δ_{ij} and ϵ_{ij} the random error for ith treatment, jth block.

RESULTS

Table 1 shows the effects of increasing DHA on the yield, composition and processing characteristics of milk. Increasing DHA in the range 16–24 kg DM significantly increased the yields of milk ($P < 0{\cdot}01$), fat ($P < 0{\cdot}01$), protein ($P < 0{\cdot}001$), casein ($P < 0{\cdot}01$) and lactose ($P < 0{\cdot}001$).

Increasing the DHA resulted in significantly higher ($P < 0{\cdot}05$) concentrations of total protein, casein and lactose, but had no effect on the levels of whey protein, non-protein N, fat, FFA, calcium, phosphorus and SCC. Increasing the DHA had no significant influence on the pH, rennet coagulation properties or ethanol stability of the milks.

DISCUSSION

This study investigated the effects of varying the daily allowance of pasture grass in mid lactation on milk composition and processing characteristics. Increasing DHA should lead to an increase in daily herbage intake (Stakelum, 1986; Poppi *et al.* 1987) and consequently energy intake.

The estimated DM intakes (using the n-alkane technique of Mayes *et al.* (1986) as modified by Dillon & Stakelum (1989)) for DHA of 16, 20 and 24 were 15·3, 16·4 and 17·0 kg respectively (SED 0·40). The estimated DM intake at DHA 16 was significantly lower than that at DHA 20 ($P < 0{\cdot}05$) and at DHA 24 ($P < 0{\cdot}001$) but estimated DM intakes at DHA 20 and 24 were not significantly different. The organic matter digestibility of the herbage on offer was similar across the treatments (823, 823 and

Table 1. *Influence of daily herbage allowance on the yield, composition and processing characteristics of milk*†

Characteristics	Daily herbage allowance, kg dry matter/cow			
	16	20	24	SED
Yield, kg/cow per d				
Milk	19·3[a]	21·2[b]	22·0[b]	0·64
Fat	0·74[a]	0·81[b]	0·84[b]	0·027
Protein	0·62[a]	0·70[b]	0·74[b]	0·023
Casein	0·47[a]	0·55[b]	0·57[b]	0·025
Lactose	0·89[a]	0·99[b]	1·03[b]	0·032
Concentration				
Total protein, g/kg	32·0[a]	33·2[ab]	34·1[b]	0·84
Casein, g/kg	24·3[a]	25·5[ab]	26·1[b]	0·69
Whey protein, g/kg	5·7[a]	5·7[a]	5·9[a]	0·29
Non-protein N, g/kg	0·31[a]	0·32[a]	0·32[a]	0·010
Fat, g/kg	38·2[a]	39·0[a]	37·9[a]	0·80
Free fatty acids, mmol/kg fat	6·34[a]	5·35[a]	5·55[a]	0·679
Lactose, g/kg	46·0[a]	46·5[b]	46·5[b]	0·21
Calcium, mg/l	1173[a]	1168[a]	1187[a]	26·4
Phosphorus, mg/l	680[a]	717[a]	727[a]	30·1
Somatic cell count ($\times 10^{-3}$), cells/ml	278[a]	268[a]	444[a]	160·9
Processing characteristics				
pH	6·65[a]	6·64[a]	6·67[a]	0·018
Rennet coagulation time, min				
At natural pH of milk	23·3[a]	24·5[a]	24·4[a]	2·28
At adjusted pH of 6·6	19·0[a]	19·7[a]	19·1[a]	1·27
Curd firmness, mm				
At natural pH of milk	37·6[a]	39·3[a]	39·2[a]	2·94
At adjusted pH of 6·6	40·7[a]	43·3[a]	44·1[a]	2·27
Ethanol stability at natural pH of milk, %	75[a]	76[a]	77[a]	2·8

† Values for the yields of milk, fat, protein and lactose and concentrations of fat and lactose are means of 14 replicate samples taken at weekly intervals. The values presented for the remaining characteristics are means of four replicate samples taken at 4 weekly intervals in the same period.

[a, b] Values within rows without a common superscript were significantly different: $P < 0·01$ for yields of milk and casein, minimum of $P < 0·01$ for yields of protein and lactose, minimum of $P < 0·05$ for yield of fat, $P < 0·05$ for concentrations of total protein, casein and lactose.

818 g/kg organic matter; SED 3·6). Cow live weight change was also similar across the range of DHA (0·13, 0·10 and 0·12 kg; SED 0·062). Increasing DHA resulted in an increase in daily herbage intake and consequently energy intake. Average milk yield response was 1·6 kg milk/kg herbage estimated DM intake for the first increment compared with 1·1 kg milk/kg intake for the second increment. Therefore, the differences observed in daily milk yield and milk composition were due principally to the differences in daily herbage estimated DM intake.

Varying the DHA had no effect on the FFA level in milk. In contrast, previous studies (Fleming *et al.* 1996; O'Brien *et al.* 1996) have shown that the concentration of FFA in milk decreased as the plane of nutrition of the cow was increased. However, the quantity and quality of herbage at the low DHA in the current study was considerably higher than the control diets of these previous studies.

The trends in calcium and phosphorus levels with increasing DHA are similar to those of Alichanidis & Vafopoulou (1975), who found that the plane of nutrition had no effect on their concentrations in milk.

It is generally reported that milks with high SCC ($> 5 \times 10^5$ cells/ml) have longer coagulation times during cheesemaking, inferior quality cheese and lower cheese yield compared with milks with low SCC ($< 3 \times 10^5$ cells/ml) (Auldist *et al.* 1996). In our study, DHA had no significant effect on the SCC levels, which were within the limits of the EC Council Directive ($< 5 \times 10^5$ cells/ml) for manufacturing milk.

The rennet coagulation characteristics of milks in this study were not significantly influenced by DHA. This is in agreement with the study of Kefford *et al*. (1995) who found that an improvement of diet quality in mid lactation was not accompanied by a change in rennet coagulation time or curd firmness. However, curd firmness is closely associated with casein content (Green & Grandison, 1993), which increased significantly with DHA in this study. While curd firmness of pH-adjusted milk followed a positive trend with DHA, it was not statistically significant. Grandison *et al*. (1984) found an improvement in curd firmness with the transition from a winter diet to spring grazing; however, casein contents were increased by 3·7–4·0 g/kg in that study. Casein content increased by 1·8 g/kg in the current study.

In conclusion, this study has shown that increasing DHA from 16 to 24 kg grass DM resulted in significant increases in the yields of milk, fat, protein, casein and lactose and the concentrations of total protein, casein and lactose. However, other milk compositional values, rennet coagulation properties and ethanol stability were not affected.

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