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Effect of cow genotype and feed allowance on milk composition

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ABSTRACT

The effect of strain of Holstein-Friesian and level of feed allowance on milk composition, individual milk proteins, and minerals was examined in a seasonal calving pastoral dairying system. The trial included two high genetic merit strains of either North American (OS90) or NZ (NZ90) genetics, and one strain representing NZ 1970's genetics (NZ70). Each strain was farmed under systems designed to provide total feed allowances of 4.5 to 7.0 t DM/cow/year. Milk composition was affected by strain of cow and by feed allowance. Strain of cow influenced crude protein ($P<0.05$), true protein ($P<0.01$) and casein ($P<0.01$) concentrations, with the NZ90 and OS90 strains having higher concentrations than the NZ70 strain. Increased feed allowance resulted in increased crude protein ($P<0.05$), true protein ($P<0.05$) and casein ($P<0.05$) concentrations. Strain, but not increased feed allowance affected the protein:fat ratio, with the OS90 strain having a higher ratio ($P<0.05$) than the NZ strains. Strain altered concentrations of α-casein ($P<0.05$), with NZ90 having the highest concentrations and NZ70 the lowest concentrations. No consistent effect of strain or feed allowance was determined on whey proteins except for β-lactoglobulin ($P<0.027$), where the OS90 strain had higher concentrations than the NZ strains. No consistent effect of strain or increasing feed allowance was seen on milk mineral concentrations. These results demonstrate that different selection and breeding policies have influenced major milk components which may influence milk processing and product characteristics.

Keywords: Milk composition, Holstein-Friesian, strain, level of feed

INTRODUCTION

Understanding the effect that dairy cow breeding and farm management practices have on milk characteristics is important to the dairy industry. Many new practices are instigated on-farm with little or no information on the impact that they might have on detailed milk composition and the down-stream effects on processing efficiency and product quality. It is known that breed (Back & Thomson 2005, Thomson *et al.,* 2001) and supplementary feeding of different feed types alters both the volume of milk and its composition (Turner *et al.,* 2005, Kay *et al.,* 2002, Thomson *et al.,* 2002, Thomson 1999). Changes in milk protein and fat yield impact on payout to the farmer. However, at a more detailed level, the concentration of some of the minor proteins and constituents in milk can ultimately affect the quality and quantity of products manufactured from that milk. For example, increases in concentrations of bovine serum albumin (BSA) and IgG concentrations or decreases in β- & κ-casein concentrations affect the quality and yield of cheese (Auldist *et al.,* 1996).

Use of overseas genetics has changed the genetic base of the New Zealand Holstein Friesian strain (Harris & Kolver 2001, Harris & Winkleman 2000). The Dexcel Strain trial, where three strains of Holstein Friesian cows were farmed under different feeding systems has demonstrated how strain and feed allowance has changed milk production (Kolver *et al.,* 2002, Kolver *et al.,* 2005). The study described in this paper extended the Strain trial study and aimed to examine the effect of strain of cow and feed allowance/supplementary feeding on milk characteristics to determine if there were beneficial or detrimental effects for milk producers and product manufacturers.

METHODS AND MATERIALS

Data presented were obtained from the third year (2003/2004) of the Dexcel Holstein-Friesian Strain trial (hereafter referred to as the 'Strain trial'). The trial design has been described fully by Rossi *et al.,* (2004). Briefly, the trial comprised of three strains of Holstein-Friesian cows farmed on a range of feeding systems. The strains were high breeding worth Holstein-Friesian cows of overseas origin (OS90; n=20) and New Zealand origin (NZ90; n=20) and a 1970's New Zealand Friesian strain (NZ70; n=15). The strains were evaluated in different farm systems designed to provide moderate to generous feeding allowances ranging from 4.5 to 7.0 t DM/cow/year based on different stocking rates and supplementary feed inputs (Table 1). The selection of 3 strains at the 5.5 t DM/cow/year feeding level was made so that a comparison could be made between strains at a common feeding level, where cows were receiving the same feed type (pasture only). The selection of the NZ90 herd across 4 feed levels allows the comparison of different feed levels/type within a strain.

TABLE 1: The amount (kg DM/cow) and quality (MJME/kg DM) of supplement fed to the cows across the different strains and the feed treatments within the NZ90 strain.

Strain	NZ70	NZ90	NZ90	NZ90	NZ90	OS90
t DM/cow	5.5	5.0	5.5	6.0	6.5	5.5
Pasture silage[1]	409	254	408	249	0	304
Maize silage[2]				466	670	
Maize grain[3]					259	
Total (kg DM/cow)	409	254	408	715	929	304
Av. MJME/kg DM	11.3	11.3	11.3	10.9	11.3	11.3

[1] Pasture silage 11.3 MJME/kg DM
[2] Maize silage 10.7 MJME/kg DM
[3] Maize grain 12.9 MJME/kg DM

Milk samples for analysis were taken three times (September, November and February) from cows in the 5.5 tDM/cow/year feed level (NZ70, NZ90, OS90) and NZ90 herds at different feeding levels. Cows were milked at approximately 0700 and 1500 hrs and individual milk samples collected at the evening and subsequent morning milking, then bulked to provide a daily sample for each cow. Samples for gross milk composition, somatic cell count and minerals were analysed following bulking of the samples. Samples for protein analysis were stored at -80º until analysis.

All milk samples were analysed for fat, crude and true protein, casein, lactose and total solids using an infrared milk analyser (Fourier Transform Infrared Spectroscopy [FT120]; Foss Electric, Hillerød, Denmark). Additional milk samples were also analysed by reference procedures; fat by the Rose Gottlieb method, (IDF, 1987), and Total N by macro-Kjeldahl digestion, (Barbano*, et al.,* 1991) to correct the FT120 results for matrix effects associated with strain of cow, level of feeding or stage of lactation.

Proportions of α-casein, β-casein, κ-casein, γ-casein, α-lactalbumin and β-lactoglobulin were measured using SDS-PAGE followed by densitometry (Mackle *et al.*, 1999a, Mackle *et al.*, 1999b). Bovine serum albumin and immunoglobulin G (IgG) concentrations were determined using radial immunodiffusion kits Albumin 'NL' and IgG 'NL', respectively (The Binding Site Ltd, Birmingham, UK) with modifications as described by Turner *et al.,* (2005). Lactoperoxidase (LP) activity of the milk samples was assayed as described by Turner *et al.*, (2005).

Somatic cell count was measured using an automated cell counter (Fossomatic 5000; Foss Electric). Milk mineral (magnesium [Mg]/sodium [Na]/potassium [K]/calcium [Ca]) concentrations were measured using the nitric-perchloric mixed acids wet ashing procedure by e-Lab, Hamilton, New Zealand as described by Turner *et al.*, (2005).

The data was analysed by fitting a mixed model using residual maximum likelihood (REML) in GenStat (GenStat, 2002) with strain, feed and the interactions of date of sampling with strain and feed as the fixed effects, and cow as the random effect. Somatic cell counts (SCC) were analysed following Log_{10} transformation to stabilise the variance.

RESULTS

Milk fat concentrations changed among the dates tested, with NZ90 cows tending to have higher milk fat concentration (Table 2). The significant interaction (date by strain, D*S) was a result of the milk of the NZ90 cows having a higher concentration of milk fat at the November sampling. Similarly, milk protein concentrations also changed with time and tended to be lowest in NZ70 cows. This effect was significant for true protein and casein concentrations (Table 2). Lactose concentrations were different between the strains with concentrations ranked NZ90>NZ70>OS90. There was no difference in SCC (Table 2).

There was a strain effect on the casein:protein ratio, with the herds ranked NZ90>OS90>NZ70 ($P<0.001$, Table 2). The protein:fat ratio was also different between strains, with the ranking OS90>NZ70>NZ90 ($P<0.003$). Further, this ranking did not change with time (Table 2).There was an effect of strain on α-casein only, with milk from the NZ70 cows having lower concentrations ($P<0.001$, Table 2). Concentrations of all caseins changed over time (data not shown) and the interactions indicate ranking order changed. The D*S interaction seen in α-casein concentrations was caused by concentrations in the milk of NZ90 and NZ70 cows decreasing over time, whereas concentrations increased over time in the milk of OS90 cows. The interaction for β-casein was caused by concentrations in the milk of NZ90 and NZ70 cows increasing over the 3 sampling times, whereas concentrations decreased in the milk of OS90 cows. A D*S interaction in γ-casein concentration occurred as a result of low concentrations in the milk of NZ90 cows in November. As a proportion of individual casein:total casein, there was a significant ($P<0.001$) increase in α-casein from 42% in the milk of NZ70 cows to 47% in the milk of NZ90 cows, which was similar to levels in milk of the OS90 cows (46%, SED 1%). However, proportions of other caseins did not change.

Among the whey proteins, there was an effect of strain on activity of LP (higher in milk of NZ90 cows; $P<0.018$) and concentrations of α-lactalbumin (lower in milk of OS90 cows; $P<0.005$) and β-lactoglobulin (higher in milk of OS90 cows; $P<0.027$, Table 2), with interactions caused by rankings being inconsistent and significant differences in November and February only. There was no effect of strain on IgG concentrations (Table 2). There was no effect of strain on Ca or Na concentrations in milk (Table 2). Concentrations of Mg were lower in the milk of NZ70 cows at all 3 sampling times ($P<0.045$). In contrast, concentrations of K in milk were lower in the milk of NZ90 cows at all 3 sampling times ($P<0.001$; Table 2).

As with strain effects, level of feed allowance influenced some milk component concentrations in milk from the NZ90 strain over time (Table 3). There was no effect of feeding level on milk fat concentration or SCC (Table 3). Protein components (crude protein, true protein and casein) in milk increased with increasing level of feed allowance. Lactose concentration was highest in the cows fed the 5.5 t DM feed allowance. There was no effect of level of feed allowance on the casein:protein or protein:fat ratio in milk (Table 3).

Concentrations of α-casein were higher in milk from cows on the 5.0 and 6.5 t DM feed allowance (Table 3). Whereas β-casein concentrations in milk increased with increasing feed allowance. Concentrations of κ-casein and γ-casein in milk were higher in cows fed the 6 and 6.5 t DM feed allowance (Table 3). There was no effect of increasing feed allowance on LP activity, IgG and α-lactalbumin concentrations in milk (Table 3). Concentrations of BSA were lower in milk from cows fed the 5.5 t DM feed allowance whereas β-lactoglobulin concentrations were higher in milk from cows fed 6.0 t DM (Table 3).

There was no effect of increasing feed allowance on Ca, Mg or Na concentrations in milk. Cows fed the 5.0 and 6.0 t DM feed allowance had higher K concentrations in milk.

TABLE 2: Milk composition from three strains of Holstein Friesian cows (New Zealand Low (NZ70), New Zealand High (NZ90) and Overseas (OS90)) at a common feed allowance (5.5 t DM/cow/year) determined over three sampling times during the 2003/2004 season.

	NZ70	NZ90	OS90	SED	Strain	Date[1]	D*S[2]
Concentration (%)							
Fat	4.48	4.80	4.45	0.18	0.073	<0.001	0.154
Crude Protein	3.29	3.43	3.46	0.07	0.063	<0.001	0.106
True Protein	3.04	3.18	3.22	0.08	0.043	<0.001	0.114
Casein	2.47	2.63	2.62	0.06	0.029	<0.001	0.247
Lactose	4.85	4.93	4.72	0.05	<0.001	<0.001	<0.001
SCC Log_{10}	1.63	1.53	1.66	0.13	0.479	<0.001	0.003
Ratios							
Casein:Protein	0.753	0.768	0.757	0.004	<0.001	<0.001	<0.001
Protein:Fat	0.75	0.72	0.80	0.03	0.003	<0.001	0.151
Casein (g/kg)							
α-casein	10.35	12.34	12.12	0.41	<0.001	0.002	0.056
β-casein	9.37	10.06	10.06	0.44	0.274	<0.001	<0.001
κ-casein	2.54	2.73	2.79	0.15	0.232	0.001	0.043
γ-casein	0.31	0.25	0.29	0.08	0.682	<0.001	0.743
Whey proteins (mg/l)							
LP (U/ml)	5.51	7.29	6.83	0.69	0.018	<0.001	<0.001
IgG	515.3	549.9	585.2	43.1	0.225	<0.001	0.317
BSA	217.3	242.7	242.2	13.7	0.089	<0.001	<0.001
α-lactalbumin	0.6	0.62	0.47	0.06	0.005	<0.001	<0.001
β-lactoglobulin	3.33	3.38	3.99	0.3	0.027	<0.001	0.082
Minerals (mg/100g)							
Calcium	129	134.5	130.6	2.9	0.158	0.088	0.003
Magnesium	11.01	11.66	11.64	0.29	0.045	<0.001	0.237
Sodium	37.67	35.36	37.74	2.42	0.501	<0.001	0.553
Potassium	162.3	152.7	164.1	3.5	<0.001	<0.001	0.707

[1] Date of sampling
[2] Date by strain interaction

TABLE 3: Milk composition from New Zealand Holstein Friesian cows offered 4 different feed allowance (5, 5.5, 6.0, 6.5 tDM) determined over three sampling times during the 2003/2004 season.

	5.0	5.5	6.0	6.5	SED	Feed	D*F[1]
Concentration (%)							
Fat	4.66	4.80	4.87	4.96	0.18	0.361	0.001
Crude Protein	3.49	3.43	3.69	3.69	0.07	<0.001	<0.001
True Protein	3.25	3.18	3.47	3.47	0.08	<0.001	<0.001
Casein	2.66	2.63	2.84	2.84	0.06	<0.001	<0.001
Lactose	4.86	4.93	4.80	4.85	0.05	<0.001	0.003
SCC Log_{10}	1.76	1.53	1.71	1.82	0.13	0.0071	0.838
Ratios							
Casein:Protein	0.763	0.768	0.769	0.770	0.004	0.116	0.061
Protein:Fat	0.76	0.72	0.76	0.75	0.03	0.180	<0.001
Casein (g/kg)							
α-casein	12.96	12.34	12.64	13.07	0.41	0.002	0.023
β-casein	9.69	10.06	10.42	10.56	0.44	<0.001	0.302
κ-casein	2.87	2.73	3.20	3.35	0.15	<0.001	0.032
γ-casein	0.28	0.25	0.39	0.46	0.08	0.014	0.271
Whey proteins (mg/l)							
LP (U/ml)	6.37	7.29	5.87	6.93	0.69	0.155	0.003
IgG	613	550	614	604	43	0.207	0.160
BSA	266.7	242.7	270.6	276.5	13.7	0.039	<0.001
α-lactalbumin	0.60	0.62	0.68	0.65	0.06	0.231	<0.001
β-lactoglobulin	3.24	3.38	4.03	3.48	0.3	0.018	0.012
Minerals (mg/100g)							
Calcium	133.8	134.5	134.9	130.6	2.9	0.329	0.032
Magnesium	11.94	11.66	12.24	12.09	0.29	0.134	<0.001
Sodium	39.17	35.36	37.30	38.63	2.42	0.305	<0.004
Potassium	158.3	152.7	158.4	150.7	3.5	0.034	<0.001

[1] Date of sampling x feed interaction

DISCUSSION

The milk composition data presented here compares well to values reported in the literature for similar genotypes and times of the year. Friesian cows of NZ origin produce milk with higher concentrations of fat and protein and lower lactose concentrations than Holstein Friesian cows of US origin (Auldist *et al.,* 2000, Kolver *et al., 2005*). The increased fat, protein and casein concentrations as the season progressed from peak lactation have also been previously reported (Mackle *et al.,* 1997, Auldist *et al.,* 1998, Mackle *et al.,* 1999b). Concentrations of components measured in milk of the NZ90 cows are similar to those reported previously for NZ pasture-fed Friesians (Mackle *et al.,* 1997, Audist *et al.,* 1998, Mackle *et al.,* 1999b). For the individual casein and whey proteins, values are similar to those published by Auldist *et al.,* 2000. LP activities are similar to those previously reported for Friesian cows (Back & Thomson 2005).

The main results demonstrated in this trial showed that the milk from the NZ90 cows contained higher concentrations of fat, crude protein and casein than the other two strains, and that in mid-late lactation, the level of feed the NZ90 cows received altered crude protein concentration. The increase in feed allowance was complicated with the diet changing with increasing feed allowance (Table 1). Thus, when comparisons are made across the herds at the higher feeding levels, any potential changes in milk composition could be due to the type of supplement, not the amount. Interestingly, level of feed made no difference to the fat content of the milk. The cows on the 6.0 and 6.5 t DM/cow/year feeding levels produced milk with similar concentrations of protein and casein despite the different feed allowance.

The selection for greater MS production in New Zealand cows resulted in the NZ90 cows having a higher casein: protein ratio while there was a higher protein: fat ratio in the milk of the OS90 cows. However, there was no difference in the protein:fat ratio between the NZ70 and NZ90 cows despite selection for increased MS production. The greater casein:protein ratio was due to the increase in proportion of α-casein as a proportion of total casein in the milk of the NZ90 cows. Strain also influenced the concentrations of whey proteins as BSA was elevated in the milk of NZ90 and OS90 cows in November and February respectively whereas the concentrations of β-lactoglobulin were higher in the milk of the OS90 cows.

Changes in proportions of fat, casein and whey proteins can affect clotting time, firmness and cheese yield (Marziali & Ng-Kwai-Hang 1986). If farmers were to use these results for herd selection these changes in milk composition would have to be weighed against differing milk volumes, milk value and production costs for the different strains. For example, it was found that the increased value of the milk of the OS90 cows was associated with a lower economic farm surplus, suggesting that although their milk might be worth more, the cost of production was higher (Thomson *et al.,* 2005).

The lower protein and casein concentration in the milk of the NZ70 cows would be detrimental to cheese manufacturing as could the increase in BSA in the milk of the NZ90 and OS90 cows in November and February respectively. However, the slightly higher casein: protein ratio of the NZ90's cows could be of benefit for cheese manufacturing. Thomson *et al.,* (2005) reported that milk from NZ90 cows had a greater value than that of the NZ70 cows, and the economic farm surplus was also higher. The higher β-lactoglobulin concentrations in the milk of the OS90 cows suggests that there may be more fouling of heat exchangers at the processing plant. However, the higher protein:fat ratio in the milk of the OS90 cows could be of benefit for processors as the protein: fat ratio has been reported as being the most important aspect of milk composition influencing product yield, the value of the mix of products processed, the value of the milk to the processor (Paul 1985), and that the end product prices is favoured by milk with a higher protein: fat ratio (Norman *et al.,* 1991).

These results demonstrate the value of monitoring the effect that changes in dairy cow breeding and farm management practises have on milk characteristics. Many different factors need to be considered by farmers, product manufacturers and the dairy industry as a whole as to the most profitable system to run, and the best use of milk for both increased profit and high product quality.

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