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Breed and heterosis effects for milk protein composition estimated in two stages of lactation in New Zealand dairy cows

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ABSTRACT

The aim of this study was to estimate breed and heterosis effects for milk protein composition found within the two main breeds farmed in New Zealand, Holstein-Friesian (HF) and Jersey (J). Groups of 20 F, 20 J and 20 HFxJ crossbred cows (3 years and older) calved at pasture between July and September 2003 and were monitored throughout the 2003/04 season. Breed and heterosis effects were estimated for daily yields of milk, crude protein, true protein and casein and concentrations of crude protein, true protein, casein, α-casein, β-casein, κ-casein, α-lactalbumin and β-lactoglobulin, bovine serum albumin (BSA) and immunoglobulin G (IgG). Breed effects were significant ($P<0.05$) for all traits except for β-lactoglobulin, BSA and IgG. Compared to J cows, HF cows had significantly ($P<0.05$) higher daily yields of milk (+5.32 kg), crude protein (+0.13 kg), true protein (+0.11 kg) and casein (+0.10 kg) but significantly ($P<0.05$) lower concentrations of crude protein (-0.50 g/kg), true protein (-0.51 g/kg), casein (-0.45 g/kg), α-casein (-3.77 g/kg), β-casein (-2.08 g/kg), κ-casein (-1.74 g/kg) and α-lactalbumin (-0.14 g/kg). Estimates of heterosis effects for concentration of milk proteins were negative but only significant for κ-casein (-0.60 g/kg). These results show that that the individual protein fractions of milk are affected by breed but crossbreeding has no beneficial effect on milk protein composition.

Keywords: breed; heterosis; milk proteins.

INTRODUCTION

Historically, Jersey (J) cows dominated the national herd until the late 1960's with the payout based on milkfat. However, by 1970 Holstein-Friesian (HF) cows were the dominant dairy breed due to changes in farm management and a greater emphasis on milk volume and protein production. Recently, crossbreed cows are emerging as a breed in their own right, with 47% of the national herd being HF, 30.1% crossbred HFxJ, 14.6% J and 8.4% other breeds including Ayrshire, Milking Shorthorn, Guernsey, and Brown Swiss and their crosses (LIC 2006). Crossbreed cows are defined as having at most 13/16 of any one breed.

Significant breed differences and heterosis for yields of milk, fat and protein (Ahlborn-Breier & Hohenboken, 1991; Harris, 2005) and for live weight, longevity, fertility and somatic cell score (Harris, 2005) have been reported for New Zealand dairy cattle. These results have encouraged many farmers in New Zealand to use crossbreeding systems as an alternative to increase farm profit (Montgomerie, 2002).

Composition of milk protein can be affected by many factors including cow genotype (Mackle *et al.,* 1999), strain (Turner *et al.,* 2005), breed (McLean *et al*., 1984; Auldist *et al.,* 2004), feeding level (Turner *et al.,* 2005) and, too a lesser extent, stage of lactation (Auldist *et al.,* 1998) and supplementary feed when cows are fed pasture (Mackle *et al.,* 1999). These factors have been known to change the amount of individual casein and whey proteins and the casein to whey ratio, which can impact on processing. The amount and type of protein in milk influences the yield and quality of cheese, caseinate and skim milk powder (Dalgleish, 1992), which are valuable products for the New Zealand dairy industry. Little is known about the effect of crossbreeding on the concentration and composition of milk proteins and given the changes in breed composition within the New Zealand dairy industry, it is important to evaluate this.

The aim of this study was to estimate, at two stages of lactation, the breed and heterosis effects for milk protein composition found within HF and J cows, the two main breeds farmed in New Zealand.

METHODS AND MATERIALS

The experiment was carried out in compliance with the guidelines of the Ruakura Animal Ethics Committee. A herd of mixed breed dairy cows (20 HF, 20 J and 20 crossbred HFxJ cows) calved at pasture between July and September 2003. Cows ranged in age from 3 to 10 years. Breed composition and Breeding Worth (BW) of cows selected for each breed group were: Holstein-Friesian (HF:J 16/0, BW 105), Jersey (HF:J 0/16, BW 96), crossbred (HF:J 4/12 to 12/4, BW 112).

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The cows were grazed on 2 farmlets in an all-pasture system with 10 cows balanced by age of each breed per farmlet at a stocking rate of 3.3 cows/ha.

Cows were milked at approximately 6:30 and 15:30 h daily and yields recorded using in-line milk meters (Westfalia Surge Metatron P21). Every 7 days, PM and AM milk yields were recorded and samples collected. A proportional subsample from PM and AM milk was bulked to form a composite sample for analysis. This was analysed for milk protein concentration (crude protein, true protein and casein) on an infrared milk analyser (Fourier Transform Infrared Spectroscopy [FT120], Foss Electric, Hillerød, Denmark). Individual milk protein composition was determined twice during the season: October (peak lactation) and February (mid lactation). Individual casein and whey proteins were quantified by high performance liquid chromatography (HPLC). Proportions of α-casein, β-casein, κ-casein, α-lactalbumin and β-lactoglobulin were quantified using a Shimadzu CL10/A system with a Phenomenex Jupiter column as described by Back (2002). Bovine serum albumin (BSA) 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).

All data were analysed using the MIXED procedure of SAS (Statistical Analysis System, version 9.1; SAS Institute Inc., Cary, NC, USA). Breed and heterosis effects were obtained after fitting the following mixed linear model:

$$y_{ijkl} = \mu + S_i + H_j + C_k + \sum_{q=1}^{2} \varphi_q a^q + \beta f + \lambda h + e_{ijkl}$$

where:

Y_{ijkl} is the observation l taken in cow k, herd j and lactation stage i.

μ is a general mean.

S_i is the fixed effect of lactation stage i.

H_j is the random effect of herd j.

C_k is the random effect of cow k.

φ_q are regression coefficients associated with the linear (q=1) and quadratic (q=2) effects of age of cow.

β is the regression coefficient associated with the linear effect of proportion of Holstein-Friesian (f).

λ is the regression coefficient associated with the linear effect of heterosis (h) between Friesians and Jerseys.

e_{ijkl} is residual random error associated to observation y_{ijkl}.

The estimate of the regression coefficient associated with of proportion of Holstein-Friesian (β) provides an estimate of the breed difference between Holstein-Friesian and Jersey. The estimate of the regression coefficient associated with the linear effect of heterosis (λ) provides an estimate of the absolute difference between the expected performance of a first cross cow (HFxJ) with respect to the average of the two straight breeds (HF and J).

Least squares means for each breed and lactation stage were obtained after fitting another mixed linear model that considered the fixed effects of breed group (Holstein-Friesian, Jersey and crossbred), lactation stage (peak and mid) and their interaction, the random effects of herd and cow and the fixed effect and cow age fitted as covariables with linear and quadratic effects. Using the Akaike's information criterion, a compound symmetry error structure was determined as the most appropriate residual covariance structure for repeated measures over time within cows. Multiple comparisons were performed between breed groups and lactation stages; significance was declared at P<0.05.

RESULTS

Least square means for the daily yields of milk and protein and concentration of protein components of each of the breed groups and lactation stage are shown in Table 1. Breed and heterosis effects over the whole lactation are shown in Table 2. For the yield traits, over a whole lactation, HF cows had significantly (P<0.05) greater daily yields of milk (+5.32 kg/day), crude protein (+0.13 kg/day), true protein (+0.11 kg/day and casein (+0.10 kg/day) compared to J cows (Table 2). As would be expected, differences in yields were greater at peak lactation than mid lactation (Table 1). Conversely, for the concentration traits, over a whole lactation HF cows had significantly (P<0.05) lower concentrations of crude protein (-0.50 g/kg), true protein (-0.51 g/kg), casein (-0.45 g/kg), α-casein (-3.77 g/kg), β-casein (-2.08 g/kg), κ-casein (-1.74 g/kg) and α-lactalbumin (-0.14 g/kg) than J cows (Table 2). There were no significant breed effects on concentration of β-lactoglobulin, BSA and IgG. Differences in concentrations of the individual proteins were lower in peak lactation compared to mid lactation (Table 1).

Stage of lactation had a significant effect (P<0.05) on all traits except on concentration of true protein, β-lactoglobulin and IgG. Significant (P<0.05) interactions between breed and stage of lactation were detected only for milk yield and κ-casein (Table 1).

Table 1: Least squares means and standard errors for daily yields of milk and protein and concentration of protein components of Holstein-Friesian (HF), Jersey (J) and crossbred (HFxJ) cows in two stages of lactation.

	Peak-lactation			Mid-lactation			Probability		
	HF	HFxJ	J	HF	HFxJ	J	Breed	S[1]	BxS[2]
Milk yield (kg)	$21.71^{a}\pm0.66$	$18.75^{b}\pm0.66$	$15.22^{c}\pm0.66$	$15.76^{a}\pm0.66$	$13.36^{b}\pm0.66$	$10.66^{c}\pm0.066$	***	***	*
Crude protein yield (kg)	$0.77^{a}\pm0.02$	$0.69^{b}\pm0.02$	$0.62^{c}\pm0.02$	$0.57^{a}\pm0.02$	$0.50^{b}\pm0.02$	$0.44^{c}\pm0.02$	***	***	NS
True protein yield (kg)	$0.73^{a}\pm0.02$	$0.66^{b}\pm0.02$	$0.59^{c}\pm0.02$	$0.53^{a}\pm0.02$	$0.47^{b}\pm0.03$	$0.42^{b}\pm0.02$	***	**	NS
Casein yield (kg)	$0.59^{a}\pm0.02$	$0.54^{b}\pm0.02$	$0.49^{c}\pm0.02$	$0.44^{a}\pm0.02$	$0.39^{b}\pm0.02$	$0.35^{b}\pm0.02$	***	***	NS
Crude protein (g/kg)	$3.57^{a}\pm0.07$	$3.73^{a}\pm0.07$	$4.06^{b}\pm0.07$	$3.63^{a}\pm0.07$	$3.77^{a}\pm0.07$	$4.16^{b}\pm0.07$	***	*	NS
True protein (g/kg)	$3.40^{a}\pm0.07$	$3.57^{a}\pm0.07$	$3.91^{b}\pm0.07$	$3.41^{a}\pm0.07$	$3.56^{a}\pm0.07$	$3.93^{b}\pm0.07$	***	NS	NS
Casein (g/kg)	$2.75^{a}\pm0.06$	$3.89^{a}\pm0.06$	$3.22^{b}\pm0.06$	$2.81^{a}\pm0.06$	$2.93^{a}\pm0.06$	$3.26^{b}\pm0.06$	***	*	NS
α-casein (g/kg)	$16.67^{a}\pm0.49$	$17.39^{a}\pm0.49$	$19.97^{b}\pm0.49$	$17.77^{a}\pm0.48$	$18.78^{a}\pm0.49$	$21.83^{b}\pm0.49$	***	***	NS
β-casein (g/kg)	$12.87^{a}\pm0.42$	$13.26^{ab}\pm0.42$	$14.32^{b}\pm0.42$	$14.59^{a}\pm0.42$	$15.21^{a}\pm0.42$	$17.01^{b}\pm0.42$	**	***	NS
κ-casein (g/kg)	$4.17^{a}\pm0.21$	$4.37^{a}\pm0.21$	$5.55^{b}\pm0.21$	$4.15^{a}\pm0.21$	$4.67^{b}\pm0.21$	$6.23^{c}\pm0.21$	***	**	*
α-lactalbumin (g/kg)	$0.90^{a}\pm0.03$	$0.99^{ab}\pm0.03$	$1.02^{b}\pm0.03$	$0.83^{a}\pm0.03$	$0.94^{a}\pm0.03$	$1.00^{b}\pm0.03$	***	*	NS
β-lactoglobulin (g/kg)	4.64±0.30	5.08±0.28	5.03±0.35	4.55±0.29	4.96±0.31	4.94±0.28	NS	NS	NS
BSA (mg/kg)	208.9±14.7	174.0±14.7	175.8±14.7	233.1±14.6	233.8±14.5	207.5±14.6	NS	***	NS
IgG (mg/kg)	477.3±32.3	537.6±32.5	558.4±32.7	499.2±31.9	541.0±32.0	539.0±32.2	NS	NS	NS

[a, b, c]Means with different superscript with each row and stage of lactation differ significantly (P<0.05).
[1]Stage of lactation.
[2]Interaction between breed and stage of lactation.

Table 2: Breed and heterosis effects for daily yields of milk and protein and concentration of protein components.

	Breed effect[1]	Heterosis effect[2]
Milk yield (kg)	5.32***±0.96	0.32±0.99
Crude protein yield (kg)	0.13***±0.03	0.01±0.03
True protein yield (kg)	0.11***±0.03	0.01±0.03
Casein yield (kg)	0.10***±0.02	0.01±0.01
Crude protein (g/kg)	-0.50***±0.10	-0.11±0.10
True protein (g/kg)	-0.51***±0.10	-0.11±0.10
Casein (g/kg)	-0.45***±0.08	-0.12±0.09
α-casein (g/kg)	-3.77***±0.62	-0.92±0.67
β-casein (g/kg)	-2.08***±0.45	-0.64±0.49
κ-casein (g/kg)	-1.74***±0.29	-0.60*±0.32
α-lactalbumin (g/kg)	-0.14**±0.04	0.04±0.04
β-lactoglobulin (g/kg)	-0.29±0.36	0.43±0.38
BSA (mg/kg)	26.5±18.1	-8.1±18.2
IgG (mg/kg)	-37.2±43.1	62.4±46.1

* P<0.05, **P<0.01, ***P<0.001.
[1] Difference Holstein-Friesian – Jersey.
[2] Difference first cross cow Holstein-FriesianxJersey – ((Holstein-Friesian + Jersey)/2).

Estimates of heterosis effects demonstrated by crossbred cows were negative for concentrations of protein components but were significant (P<0.05) only for κ-casein (-0.60 g/kg, Table 2).

DISCUSSION

Levels of production found in this study are typical values for seasonal calving herds in New Zealand. Compared with HF cows, J cows produced milk with higher concentrations of nearly all types of proteins measured in lower milk yields. Similar results have been reported previously in grazing cows in New Zealand (Auldist *et al.,* 2004) and Australia (McLean *et al.,* 1984). It has been shown that cheese making properties can be enhanced by high concentration of α- β- and κ-casein (Dalgleish 1992; Auldist *et al.,* 2004; Wedholm *et al.,* 2006) and these higher concentrations of proteins would contribute to J milk generating higher cheese yields than HF milk. However, this difference is not solely due to differences in protein as Auldist *et al.* (2004) demonstrated that differences in cheese-making properties of milk from J and HF cows were significantly related to the concentrations of solids in milk rather than concentrations of individual proteins. Breed differences for concentrations of individual proteins increased from peak to mid lactation suggesting that patterns of concentration of milk components would be different between the two breeds considered but the interactions between breed and stage of lactation were not significant.

The least squares means for the different milk traits estimated for each stage of lactation can be used along with breed and heterosis effects to predict performance of cows with different breed compositions (Ahlborn-Breier & Hohenboken, 1991) under different mating systems (Lopez-Villalobos *et al.,* 2000). Favourable crossbreeding effects have previously been reported for production, fertility and health traits in New Zealand and other countries (Lopez-Villalobos, 1998) and this has encouraged farmers to use crossbreeding systems to increase farm profit. There is little published evidence of heterosis for milk protein composition traits and this paper provides some insight of these effects in grazing dairy cattle. While the estimates of heterosis effects for concentrations of milk proteins were negative, this was only significant for κ-casein (-0.60 g/kg). Caution should be taken when interpreting results from this study because the statistical power to estimate breed and heterosis effects was low due to the small number of cows in each breed group.

In conclusion this study shows that individual protein fractions in the milk are affected by breed. A significant positive effect of crossbreeding was not demonstrated for concentration of individual proteins as would have been predicted based on results from first or second cross animals. Implications of these results need to be considered carefully for future breeding strategies.

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