

THE RELATIONSHIP BETWEEN MILK PROTEIN PHENOTYPES AND LACTATION TRAITS IN AYRSHIRES AND JERSEYS

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Summary

A total of 3,610 Ayrshire and 1,711 Jersey cows were phenotyped for the genetic variants of α_{s1} -casein, β -casein, κ -casein, β -lactoglobulin and α -lactalbumin. Least squares analyses showed possible associations between milk protein phenotypes and lactational production traits. Depending on lactation number, β -casein phenotypes in Ayrshires were associated with milk production ($A^2A^2 > A^1A^2 > A^1A^1$), and with milk protein content. In the third lactation, Ayrshire cows with β -casein A^1A^1 produced milk with 3.43% fat compared to 3.37% fat for β -casein A^2A^2 . In Ayrshire, κ -casein phenotypes affected the protein content during the three lactations ($BB > AB > AA$) and β -lactoglobulin phenotypes significantly influenced the milk fat during the first lactation (4.06% for AA and 3.97% for BB). In Jerseys, protein content of milk was influenced by phenotypes of α_{s1} -casein (3.98% for CC v/s 3.86% for BB in the first lactation). In the third lactation, κ -casein AA of Jersey milk contained 5.35% fat compared to 4.82% for phenotype BB. The effects of β -lactoglobulin phenotypes on protein content were apparent in Jerseys during the second lactation with the A variant being superior to the B (4.00% for AA v/s 3.87% for BB).

(Key Words : Ayrshire, Jersey, Genetic Variants, Milk, Fat, Protein)

Introduction

The major bovine milk proteins have been shown to exhibit genetic polymorphisms. Numerous studies worldwide have reported that the existence and frequency distributions of specific genetic variants in dairy cattle are breed dependent. There is much interest in using milk protein genes as marker genes for milk yield and composition. Ng-Kwai-Hang and Grosclaude (1992) gave a comprehensive review of genetic polymorphism of milk protein and its potential application to improve profitability of the overall dairy industry. In the literature, there are conflicting results regarding the associations between milk protein phenotypes and milk yield and composition. Those inconsistencies are due to differences in population sizes, breeds of cattle, frequency distributions of genetic variants, methods of expressing milk yield and composition and most importantly, the

rigour of statistical analysis to adjust for other more important factors contributing to milk production and composition. Most of the studies involving populations that are large enough to permit meaningful interpretations of data are confined to the Holstein breed (Ng-Kwai-Hang et al., 1984, 1986, 1990; Gonyon et al., 1987; Aleandri et al., 1990; Bovenhuis, et al., 1992). The objective of this study was to investigate the possible associations between genetic variants of α_{s1} -casein, β -casein, κ -casein and β -lactoglobulin and lactational production of milk, fat and protein for three lactations in Ayrshire and Jersey cows.

Materials and Methods

Data collection for lactation traits

This study was based on the first, second and third lactation production records of all the available cows distributed in 65 Ayrshire and 33 Jersey herds registered with Quebec Dairy Herd Analysis Service. The Ayrshire herds were randomly selected from a total of 423 herds and the Jersey herds represented all the herds for that breed registered in the milk recording programme. On an approximately monthly basis, milk production was

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recorded for the morning and afternoon milkings throughout the lactation period. A sample of the combined milkings were sent to the laboratory for analysis of fat and protein with an infrared Multispec II (Multispec Inc., Wheldrake, York, England) milk analyzer previously calibrated according to the manufacturer's specifications. Somatic cell count was determined with a Fossomatic cell counter (A/S N. Foss Electric, Hillerød, Denmark). The monthly test-day analyses for fat and protein contents and somatic cell count were used to calculate the respective lactational parameters according to established standard procedures. From the production files, data pertaining to test-day, lactation number, calving date, fat and protein contents, somatic cell count, 305-d lactation milk, fat and protein yields were retrieved for the selected individual cows.

Phenotyping of milk proteins

Vertical polyacrylamide gel electrophoresis under alkaline and reducing conditions were used to determine the phenotypes of α_{s1} -casein, β -casein and κ -casein (Ng-Kwai-Hang et al., 1984). The differentiation of variants A¹, A² and A³ of β -casein necessitated the running of a second electrophoresis under acidic conditions. Genetic variants of β -lactoglobulin and α -lactoglobulin were characterised by electrophoresis in 12% polyacrylamide at pH 8.2 (Ng-Kwai-Hang and Kroeker, 1984). To avoid errors due to misidentification or mix-up of samples, the phenotyping were done on samples collected on three different test days. The results obtained for individual cows were compared and retained only if they were consistent. A file was created to match each cow with its phenotype for α_{s1} -casein, β -casein, κ -casein, β -lactoglobulin and α -lactalbumin.

Statistical analyses

Because of differences in frequency distributions of phenotypes for milk proteins and differences in parameters of production traits in Ayrshires and Jerseys, analyses were carried out separately for the two breeds. The associations of milk protein phenotypes with milk, fat and protein yields and percentages of fat and protein were analysed separately for the first, second and third lactations. The least squares model used included herd, age of cow at calving, year and month of calving, phenotype of α_{s1} -casein, β -casein, κ -casein and β -lactoglobulin. Somatic cell count transformed to the natural logarithm scale was included in the model as a covariate.

After matching complete sets of production data in Ayrshires, there remained 1,473, 998 and 660 cows for

the first, second and third lactation, respectively. There were 17, 17 and 20 subclasses for age at calving in the three lactations, respectively. Each of the subclasses for age at calving was classified on a monthly interval and represented cows which calved within the age of 23 to 39 mo for the first lactation, 36 to 52 mo for the second lactation and 48 to 67 mo for the third lactation. For all three lactations, there were 9 subclasses, of six months each, for season at calving which occurred from September, 1987 to August, 1992. In the studied Ayrshire population, 99.9% of the cows were of the BB phenotype for α_{s1} -casein and 100% were homozygous B for α -lactalbumin. Hence, there was no subclassification for α_{s1} -casein and α -lactalbumin. Phenotypes for β -casein were divided into three subclasses corresponding to A¹A¹, A¹A² and A²A². There were three subclasses (AA, AB, BB) each for κ -casein and β -lactoglobulin phenotypes. Complete data sets were analysed for 464 cows in first lactation, 343 cows in second lactation and 257 cows in third lactation for the Jerseys. There were 19, 25 and 29 monthly subclasses for age at calving in the three lactations respectively. The monthly subclasses for age at calving represented cows which calved at the age of 21 to 39 mo, 34 to 58 mo and 45 to 73 mo during the three respective lactations. There were five subclasses of six months each for season of calving during all three lactations. The semi-annual calving seasons occurred from September, 1989 to August, 1992. Alpha_{s1}-casein phenotypes were classified into three subclasses (BB, BC, CC). There were six subclasses for β -casein phenotypes (A¹A¹, A¹A², A¹B, A²A², A²B, BB) and three each for κ -casein and β -lactoglobulin (AA, AB, BB). The effect of α -lactalbumin phenotype was not fitted in the model because only the homozygous B type was identified in all the cows.

Results and Discussion

Frequency distribution of milk protein phenotypes

Table 1 shows the frequency distribution of the phenotypes of five milk proteins in Ayrshires and Jerseys. Of the 3,603 Ayrshire and 1,708 Jersey samples which were analysed, all were of the BB phenotype for α -lactalbumin. Frequencies of various detected phenotypes for the remaining four milk proteins were different for the two breeds. Two phenotypes, BB and BC were identified for α_{s1} -casein with the former accounting for 99.9% in Ayrshires. In contrast, a relatively higher frequency of the C variant of α_{s1} -casein was observed in Jerseys with 16.4 and 53.4%, respectively for phenotypes CC and BC. A

frequency of 99.4% for α_{s1} -casein BB and 0.6% for α_{s1} -casein BC has been reported in Ayrshire by Lin et al. (1986). Other workers (Aschaffenburg, 1968; Hoogendoorn et al., 1969; Li et al., 1972) found 100% of the B variant of α_{s1} -casein in Ayrshires. The frequency of 43.1% for C variant of α_{s1} -casein in Jerseys is in agreement with the range of values (0.26 to 0.43) found in literature (Aschaffenburg, 1968; Hoogendoorn et al., 1969; Li and Gaunt, 1972; McLean et al., 1984; Beck and Kristiansen, 1990). The A¹ variant of β -casein occurred at a higher frequency in Ayrshire and a lower frequency than the A² variant in Jerseys. The ratio of A¹ to A² β -casein was 59:38 in Ayrshires and 19:50 in Jerseys. The low frequencies of A³ and B variants of β -casein in Ayrshires occurred only as heterozygotes in combination with variant A¹ or A². There was a higher frequency of B variant of β -casein in Jerseys with 8.41, 9.24 and 35.37% of the cows being of phenotypes BB, A¹B and A²B, respectively. The frequency distributions of the various phenotypes of β -casein in Ayrshires and Jerseys are similar to those of other workers (Aschaffenburg, 1968; Hoogendoorn et al., 1969; Li and Gaunt, 1972; McLean et

al., 1984; Lin et al., 1986; Beck and Kristiansen, 1990). Kappa-casein and β -lactoglobulin had each two variants, A and B, in the two breeds, giving a possibility of three phenotypes AA, AB and BB. There was a prevalence of κ -casein AA (77.7%) in Ayrshires and of κ -casein BB (55.2%) in Jerseys. According to Aschaffenburg (1968), the A allele of κ -casein tends to be more frequent in the majority of breeds, except in the Jersey and the French Normande. The low frequency of the A allele of β -lactoglobulin among the Ayrshires as indicated in table 1 is in accordance with reports of Hoogendoorn et al. (1969), Li and Gaunt (1972) and Lin et al. (1986). The A variant of β -lactoglobulin occurred at a higher frequency in Jerseys with 17.3% AA and 53.81% AB when compared to Ayrshires with 5.0% AA and 38.1% AB.

Production data for Ayrshires and Jerseys

Table 2 shows the 305-day complete lactation data for Ayrshires and Jerseys which were retained for analysis after discarding records that did not have complete information regarding phenotypes for α_{s1} -casein, β -casein, κ -casein and β -lactoglobulin; somatic cell count; age at calving and; season of calving. The lactational yields and percentages of fat and protein were within the ranges of the breeds registered in the Quebec milk recording programme (PATLQ, 1995). Ayrshires outproduced the Jerseys by 1,638 to 1,736 kg of milk per lactation during the first three lactations. Jersey milk contained higher concentrations of fat (4.84 to 4.91%) and protein (3.91 to 3.96%) than Ayrshire milk which contained 3.99 to 4.07% fat and 3.36 to 3.40% protein. In Ayrshires, milk fat percentage decreased with increasing lactation number and protein content was highest during the second lactation. In Jerseys, protein content was also highest during the second lactation and fat content was similar during the first two lactations but declined during the third lactation. Higher milk production in Ayrshires overcompensated for the lower component percentages as shown by their lactational yields of fat and protein when compared to Jerseys.

Environmental factors affecting production traits

The analyses of variance for the considered environmental factors on milk yield and fat and protein contents are shown in table 3 for Ayrshires and in table 4 for Jerseys. In both breeds, herd, age at calving and season of calving had significant effects on milk production during the three lactations. Similar observations were earlier reported (Ng-Kwai-Hang et al., 1990) for Holstein herds managed under Quebec conditions. The percentages and yields of fat and protein were also

TABLE 1. PHENOTYPE FREQUENCIES OF MILK PROTEINS IN AYRSHIRES AND JERSEYS

Milk protein	Phenotype	Ayrshire		Jersey	
		No.	%	No.	%
α_{s1} -casein	BB	3,608	99.94	516	30.16
	BC	2	0.06	914	53.42
	CC	—	—	281	16.42
β -casein	A ¹ A ¹	1,216	33.82	100	5.92
	A ¹ A ²	1,882	50.34	296	17.54
	A ² A ²	475	13.21	394	23.34
	A ² A ³	7	0.19	3	0.18
	A ¹ B	8	0.22	156	9.24
	A ² B	8	0.22	597	35.37
	BB	—	—	142	8.41
κ -casein	AA	2,803	77.71	123	7.20
	AB	751	20.82	643	37.62
	BB	53	1.47	943	55.18
β -lactoglobulin	AA	180	5.00	295	17.27
	AB	1,372	38.08	919	53.81
	BB	2,051	56.92	494	28.92
α -lactalbumin	BB	3,603	100	1,708	100

TABLE 2. SUMMARY OF 305-D LACTATION PRODUCTION OF AYRSHIRE AND JERSEY

Breed and Lactation #	No.	Yield (kg)						Concentration (%)			
		Milk		Fat		Protein		Fat		Protein	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Ayrshire											
1	1,473	5,808.6	26.9	235.8	1.1	194.8	0.9	4.07	0.007	3.36	0.005
2	998	6,468.9	38.0	259.2	1.5	219.3	1.3	4.02	0.009	3.40	0.006
3	660	6,814.3	50.8	271.7	2.1	230.0	1.7	3.99	0.011	3.38	0.008
Jersey											
1	464	4,170.1	40.8	203.8	1.9	162.7	1.6	4.90	0.019	3.91	0.011
2	343	4,760.2	55.8	232.9	2.7	188.3	2.2	4.91	0.024	3.96	0.013
3	257	5,078.9	74.6	244.8	3.6	198.8	2.9	4.84	0.030	3.92	0.016

TABLE 3. THE F RATIOS FROM LEAST SQUARES ANALYSES OF VARIANCE FOR 305-D LACTATION YIELD AND MILK COMPOSITION FOR THREE LACTATIONS IN AYRSHIRES

Source	df	Milk yield	Fat %	Protein %	Fat yield	Protein yield
Lactation 1						
Herd	62	13.30**	5.33**	5.34**	15.09**	18.40**
Age of calving	16	4.03**	0.73	0.53	4.82**	5.19**
Season of calving	8	3.96**	0.49	2.90**	4.04**	5.29**
β -casein	2	5.51**	0.82	1.54	3.98*	7.04**
κ -casein	2	2.77**	0.92	2.90	4.91**	2.21
β -lactoglobulin	2	0.71	5.19**	0.09	0.19	0.57
Somatic cell count	1	7.34**	0.05	9.24**	7.51**	3.00
Error	1,346					
Lactation 2						
Herd	62	8.42**	4.06**	3.36**	8.32**	11.42**
Age of calving	16	2.59**	1.16	0.59	2.18**	2.94**
Season of calving	8	2.68**	1.16	2.62**	2.46*	2.48*
β -casein	2	0.28	1.57	0.30	0.78	0.22
κ -casein	2	1.22	0.00	4.56*	0.96	0.09
β -lactoglobulin	2	4.29*	2.20	1.02	2.25	4.23*
Somatic cell count	1	15.14**	2.79	2.86	21.96**	11.83**
Error	974					
Lactation 3						
Herd	62	6.43**	2.66**	2.57**	6.32**	7.70**
Age of calving	19	1.80*	1.42	0.71	2.53**	2.04**
Season of calving	8	3.79**	1.74	1.44	4.78**	2.81**
β -casein	2	1.09	2.50	3.57*	1.32	0.99
κ -casein	2	1.24	0.24	2.83	0.79	0.31
β -lactoglobulin	2	0.45	2.55	1.23	1.72	0.31
Somatic cell count	1	2.04	0.15	0.09	3.47	3.96*
Error	558					

** P < 0.01; * P < 0.05.

TABLE 4. THE F RATIOS FROM LEAST SQUARES ANALYSES OF VARIANCE FOR 305-D LACTATION YIELD AND MILK COMPOSITION FOR THREE LACTATIONS IN JERSEYS

Source	df	Milk yield	Fat %	Protein %	Fat yield	Protein yield
Lactation 1						
Herd	26	16.16**	2.33**	6.91**	19.66**	22.83**
Age of calving	18	2.02**	0.84	0.80	2.77**	2.42**
Season of calving	4	2.96*	0.11	1.70	2.69*	2.38*
α_{s1} -casein	2	0.26	1.25	5.61**	0.59	1.42
β -casein	5	0.56	1.26	1.50	0.56	0.73
κ -casein	2	0.22	0.54	1.10	0.10	0.03
β -lactoglobulin	2	1.65	0.15	1.85	1.30	3.88*
Somatic cell count	1	3.59	0.01	4.01*	3.31	1.29
Error	319					
Lactation 2						
Herd	25	14.60**	2.63**	5.50**	13.41**	17.86**
Age of calving	24	2.07**	0.66	0.83	1.70*	2.04**
Season of calving	4	2.25*	1.00	1.00	1.66	1.65
α_{s1} -casein	2	0.97	0.36	0.88	0.35	0.82
β -casein	5	1.05	0.73	1.29	0.69	0.63
κ -casein	2	1.99	0.24	0.30	0.96	2.94
β -lactoglobulin	2	0.41	0.14	4.71**	0.69	2.78
Somatic cell count	1	9.86**	0.83	5.97*	5.22*	4.88**
Error	282					
Lactation 3						
Herd	25	10.10**	2.38**	3.69**	8.12**	13.50**
Age of calving	28	2.06**	1.65**	0.93	1.62*	1.98**
Season of calving	4	0.82	0.45	1.33	0.95	1.93
α_{s1} -casein	2	0.01	0.73	0.70	0.39	0.20
β -casein	5	0.22	1.76	0.80	0.68	0.14
κ -casein	2	0.77	3.28*	0.13	1.68	1.22
β -lactoglobulin	2	0.62	0.06	0.29	0.30	0.39
Somatic cell count	1	7.82**	0.10	1.27	5.22*	5.77*
Error	140					

** P < 0.01; * P < 0.05.

consistently affected by herd. Season of calving influenced the protein content during lactation 1 and 2 in Ayrshires, but had no influence in Jerseys. Fat content in Jersey milk was affected by age of calving during the third lactation, but not during the first and second lactations.

Milk protein phenotypes and production traits in Ayrshires

Because more than 99.9% of the Ayrshire were of the BB phenotypes for α_{s1} -casein, it was not possible to determine the effects of genetic variants of this milk protein on production traits.

Table 3 shows that β -casein phenotypes significantly ($p < 0.01$) affected milk, fat and protein yields during the first lactation but not during the subsequent lactations. Figure 1 shows that β -casein A²A² produced 6,077 kg of milk compared to 5,838 for β -casein A¹A¹ during the first lactation. Although not significantly different, the trends were for lower milk yields from β -casein A¹A² cows during the second and third lactations. Other studies involving Ayrshires (Hoogendoorn et al., 1969; Lin et al., 1986) have reported no relationships between milk yield and β -casein phenotypes. Lin et al. (1986) showed that protein yield in Ayrshire were in favour of β -casein A²A².

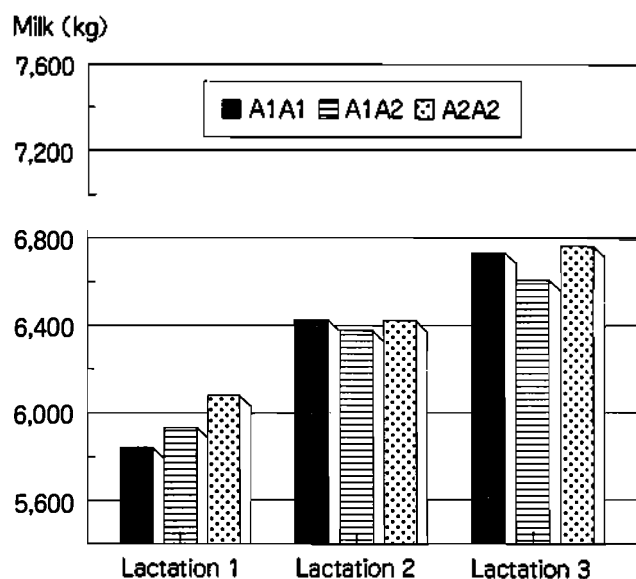


Figure 1. Association between β -casein phenotypes and 305-d milk yield for three lactations in Ayrshires.

In the Holstein breed (Gonyon et al., 1987; Aleandri et al., 1990) and in the Guernseys (Haenlein et al., 1987) no differences in milk yields were detected among the different phenotypes of β -casein. In contrast, Ng-Kwai-Hang et al. (1984; 1986; 1990) and Bovenhuis et al. (1992) reported that milk production in Holsteins were associated with β -casein variants. The genetic variants of β -casein could be classified in the following order according to a decreasing level of milk production: $A^3 > A^2 > A^1 > B$. The non-significant association between β -casein phenotypes and milk fat content is in concordance with the reports of Hoogendoorn et al. (1969) and Lin et al. (1986). Reports involving other breeds (Bovenhuis et al., 1992; Gonyon et al., 1987; Ng-Kwai-Hang et al., 1986; 1990) have indicated significant effects of β -casein phenotypes on fat and protein contents of milk. Protein in milk was associated with β -casein phenotypes (table 3) during the third and not the first or second lactation. Figure 2 shows that in lactation 3, β -casein A^1A^1 milk contained 3.43% protein compared to 3.42% for A^1A^2 and 3.37 for A^2A^2 . Although not statistically significant, the trends also showed that β -casein A^2A^2 were associated with lower milk fat during the first and second lactation.

Table 3 shows that κ -casein phenotypes significantly ($p < 0.05$) influence the protein content of milk during the second lactation. The lack of association between κ -casein phenotypes and milk composition in Ayrshires during the first and third lactation agrees with the reports

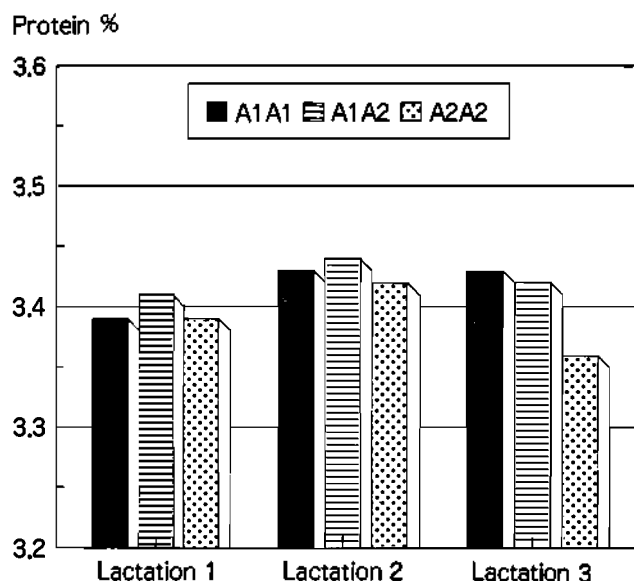


Figure 2. Association between β -casein phenotypes and protein content of milk for three lactations in Ayrshires.

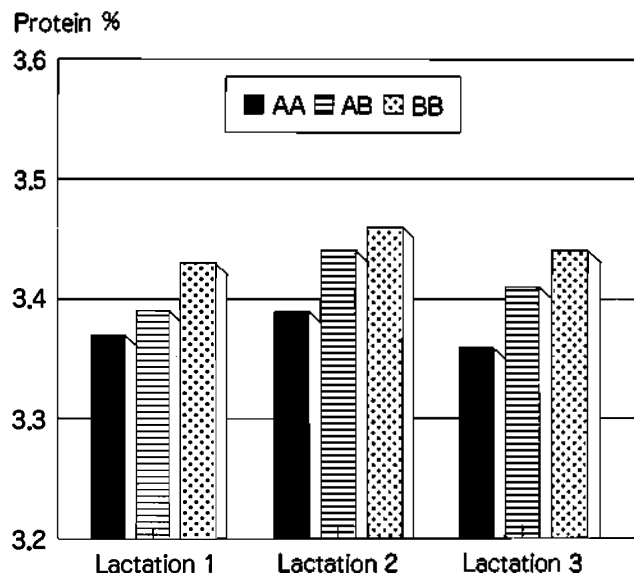


Figure 3. Association between κ -casein phenotypes and protein content of milk for three lactations in Ayrshires.

of Hoogendoorn et al. (1969) and Lin et al. (1986). Figure 3 shows the associations of κ -casein phenotypes with protein content of milk for the three lactations. In lactation 3, the protein contents were 3.36, 3.41 and 3.44% for κ -casein AA, AB and BB, respectively. In all three lactations, κ -casein BB milk contained more protein than the AA phenotype, with AB being intermediate. The

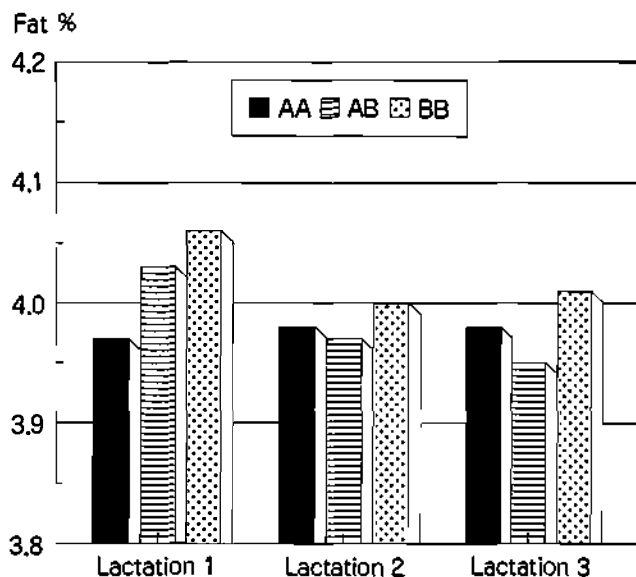


Figure 4. Association between β -lactoglobulin phenotypes and fat content of milk for three lactations in Ayrshires.

majority of studies (Aleandri et al., 1990; Bovenhuis et al., 1992; Gonyon et al., 1989; Ng-Kwai-Hang et al., 1984; 1986; 1990) on Holsteins demonstrated that κ -casein B is superior to A for protein content.

Table 3 shows that β -lactoglobulin phenotypes significantly affected milk yield during the second lactation and milk fat during the first lactation. The two reports on Ayrshires (Hoogendoorn et al., 1969; Lin et al., 1986) indicated no relationships between β -lactoglobulin phenotypes and milk production and fat content. Figure 4 shows that β -Lg BB milk contained 4.06% fat compared to 3.97% for β -Lg AA in the first lactation. Although not statistically significant ($p < 0.05$), β -lactoglobulin BB milk was also associated with higher fat content than β -lactoglobulin AA or AB in the second and third lactations. Some studies with Holsteins (Gonyon et al., 1987; Ng-Kwai-Hang et al. (1990) reported no relationships between β -lactoglobulin variants and milk fat content. Whenever any associations were shown in other breeds (McLean et al., 1984; Ng-Kwai-Hang et al., 1986; Haenlein et al., 1987; Aleandri et al., 1990; Bovenhuis et al., 1992), the B variant of β -lactoglobulin consistently contained more fat than the A variant. The non-association between β -lactoglobulin phenotypes and protein content during the three lactations in Ayrshires, as shown in table 3 is in agreement with studies on other breeds (Gonyon et al., 1987; Haenlein et al., 1987; Hill, 1993). A larger number of reports (Graml et al., 1985; Rozzi et al., 1989; Ng-Kwai-Hang et al., 1984; 1986; 1990) have demonstrated

that higher milk protein was found in cows bearing the AA phenotype of β -lactoglobulin.

Milk protein phenotypes and production traits in Jerseys

Table 4 shows no associations between phenotypes of the four milk proteins and milk yield in the three lactations of Jerseys. These results are consistent with other studies on Jerseys (Hoogendoorn et al., 1969; McLean et al., 1984; Beck and Kristiansen, 1990). Highly significant ($p < 0.01$) association between α_{s1} -casein phenotypes and milk protein content was found in the first lactation only. Figure 5 shows the protein content associated with the phenotypes of α_{s1} -casein BB, BC and CC during three lactations in Jerseys. In lactation 1, α_{s1} -casein CC milk contained 3.98% protein compared to 3.86% in the BB phenotype. Similar trends of protein content for different phenotypes of α_{s1} -casein were observed in the third lactation. The trends in the second lactation were different in that the highest protein was associated with the BC phenotype, followed by the CC and BB phenotypes of α_{s1} -casein. For Jersey milk, Hoogendoorn et al. (1969) reported significant association between genetic variants of α_{s1} -casein and protein content whereas McLean et al. (1984), and Beck and Kristiansen (1990) found no relationships. In the present study, no effects were found between phenotypes of β -casein and contents of fat and protein for all the three lactations. In contrast, Beck and Kristiansen (1990) reported that β -casein

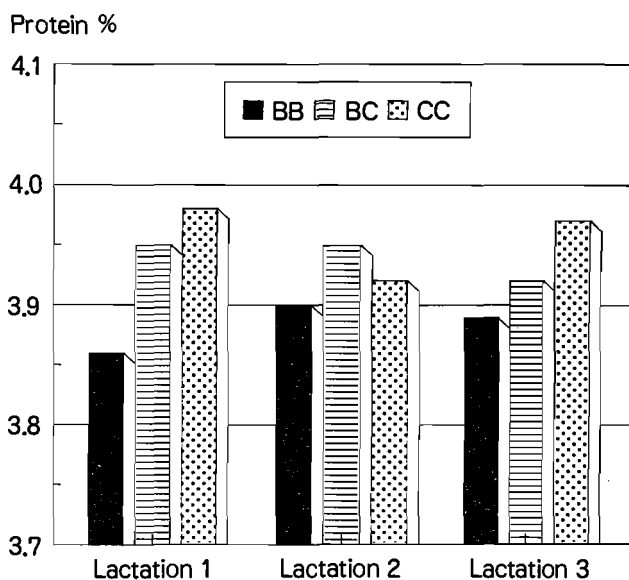


Figure 5. Association between α_{s1} -casein phenotypes and protein content of milk for three lactations in Jerseys.

phenotypes influenced milk fat content during the second lactation and milk protein during the first and second lactations. Phenotype A^2A^2 was associated with higher protein than phenotype BB. For fat content the A^1B phenotype was superior to A^2A^2 . McLean et al. (1984) reported that the fat contents of β -casein BB, A^1B , A^2A^2 milks were higher than that of A^1A^2 milk. Kappa-casein phenotypes were associated ($p < 0.05$) with fat percentage in the third lactation. Figure 6 shows that fat content of milk according to the three phenotypes of κ -casein during three lactations in Jerseys. Although the trends indicate that higher fat content was associated with the AA phenotype, it was only during the third lactation that the differences were significant ($p < 0.05$). In lactation 3, κ -casein AA milk contained 5.28% fat as compared to 4.81% for AB and 4.82% for BB phenotype. Two studies with Jerseys (McLean et al., 1984; Beck and Kristiansen, 1990) indicated no associations between κ -casein types and fat or protein content and Hoogendoorn et al. (1966) reported that the BB phenotype milk contained 0.14% more protein than the AA phenotype. Table 4 shows that β -lactoglobulin phenotypes were associated ($p < 0.01$) with protein content during the second lactation. Figure 7 shows that protein content was higher for β -lactoglobulin AA and lower for β -lactoglobulin BB milk during the first two lactations and the trend was reversed in the third lactation. For the significant trend in the second lactation, cows bearing β -lactoglobulin AA produced milk with

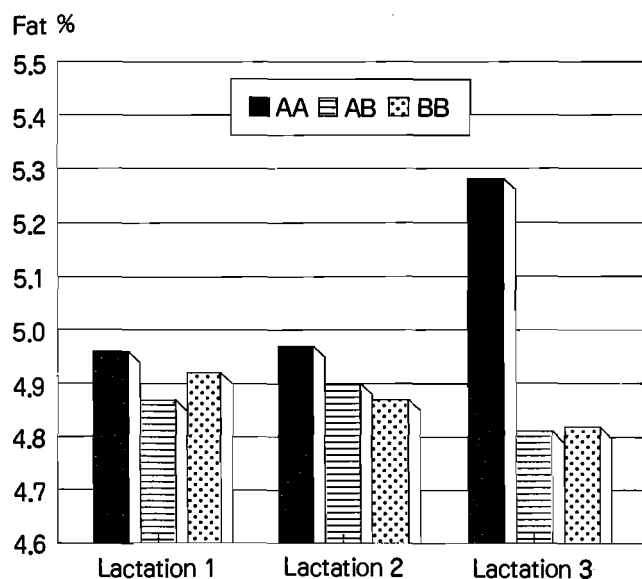


Figure 6. Association between κ -casein phenotypes and fat content of milk for three lactations in Jerseys.

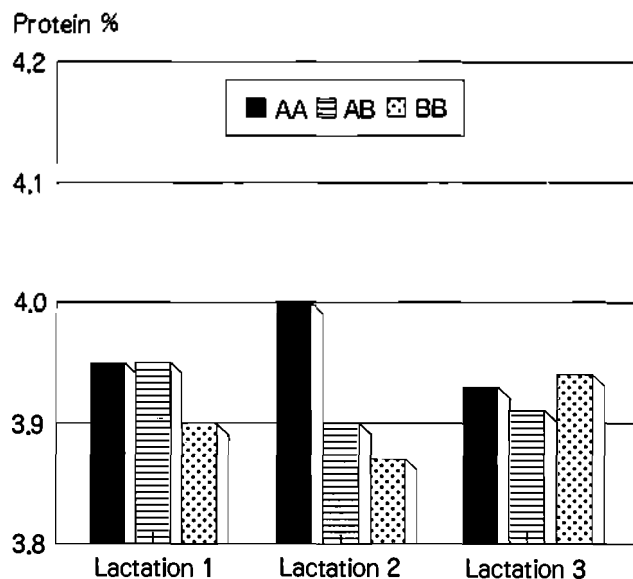


Figure 7. Association between β -lactoglobulin phenotypes and protein content of milk for three lactations in Jerseys.

4.00% protein as compared to 3.87% protein for β -lactoglobulin BB cows. Hoogendoorn et al. (1969) and Beck and Kristiansen (1990) reported no association between β -lactoglobulin phenotypes and contents of fat and protein in Jersey milk. The work of McLean et al. (1984) showed that β -lactoglobulin BB contained higher fat but lower protein than the AA phenotype.

Conclusions

Based on the results presented in this study, the frequency distributions of possible phenotypes of α_s -casein, β -casein, κ -casein and β -lactoglobulin are different for Ayrshires, Jerseys and other breeds. After adjustments are made for the effects of herd, age at calving, season of calving, any associations found between the phenotypes of a particular milk protein and lactational traits will depend on the protein system being considered, lactation number, the traits in question and the breeds involved. Certain phenotypes of β -casein and β -lactoglobulin are associated with milk yield in Ayrshires but not in Jerseys. Our results suggest that milk fat is associated with β -lactoglobulin phenotypes in Ayrshires and with κ -casein types in Jerseys. Significant differences for milk protein contents were observed according to phenotypes of β -casein and κ -casein in Ayrshires and phenotypes of α_s -casein and β -lactoglobulin in Jerseys.

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Literature Cited

- Aleandri, R., L. G. Buttazzoni, J. C. Schneider, A. Caroli and R. Davoli. 1990. The effects of milk protein polymorphisms on milk components and cheese-producing ability. *J. Dairy Sci.* 73:241-255.
- Aschaffenburg, R. 1968. Genetic variants of milk proteins: their breed distribution. *J. Dairy Res.* 35:447-460.
- Beck, A. M. and S. R. Kristiansen. 1990. Milk protein polymorphism in Danish dairy cattle and the influence of genetic variants on milk yield. *J. Dairy Res.* 57:53-62.
- Bovenhuis, H., J. A. van Arendonk and S. Kover. 1992. Associations between milk protein polymorphisms and milk production traits. *J. Dairy Sci.* 75:2549-2559.
- Graml, R., J. Buchberger, H. Klostermeyer and F. Pirchner. 1985. Pleiotrope wirkungen von β -laktoglobulin und casein genotypen auf milchinhaltstoffe des bayerischen Fleckviehs und Braunviehs. *Z. Tierz. Zuchtungsbiol.* 102:355-370.
- Gonyon, D. S., R. E. Mather, H. C. Hines, G. F. W. Haenlein, C. W. Arave and S. N. Gaunt. 1987. Associations of bovine blood and milk polymorphisms with lactation traits: Holsteins. *J. Dairy Sci.* 70:2585-2598.
- Haenlein, G. F. W., D. S. Gonyon, R. E. Mather and H. C. Hines. 1987. Associations of bovine blood and milk polymorphisms with lactation traits: Guernseys. *J. Dairy Sci.* 70:2599-2609.
- Hill, J. P. 1993. The relationship between β -lactoglobulin phenotypes and milk composition in New Zealand dairy cattle. *J. Dairy Sci.* 76:281-286.
- Hoogendoorn, M. P., J. E. Moxley, R. O. Hawes and H. F. MacRae. 1969. Separation and gene frequencies of blood serum transferrin, casein and beta-lactoglobulin loci of dairy cattle and their effects on certain production traits. *Can. J. Anim. Sci.* 49:331-341.
- Li, F. H. F. and S. N. Gaunt. 1972. A study of genetic polymorphism of milk β -lactoglobulin, α_{s1} -casein, β -casein and κ -casein in five dairy breeds. *Biochem. Genet.* 6:9-20.
- Lin, C. Y., A. J. McAllister, K. F. Ng-Kwai-Hang and J. F. Hayes. 1986. Effects of milk protein loci on first lactation production in dairy cattle. *J. Dairy Sci.* 69:704-712.
- McLean, D. M., E. R. B. Graham and R. W. Ponzoni. 1984. Effects of milk protein genetic variants on yield and composition. *J. Dairy Res.* 51:531-546.
- Ng-Kwai-Hang, K. F. and F. Grosclaude. 1992. Genetic polymorphism of milk protein. In: *Advanced Dairy Chemistry. Vol. 1. Proteins.* P. F. Fox, ed. Elsevier Science Publ. London, pp. 405-455.
- Ng-Kwai-Hang, K. F., J. F. Hayes, J. E. Moxley and H. G. Monardes. 1984. Association of genetic variants of casein and milk serum proteins with milk, fat and protein production by dairy cattle. *J. Dairy Sci.* 67:835-840.
- Ng-Kwai-Hang, K. F., J. F. Hayes, J. E. Moxley and H. G. Monardes. 1986. Relationships between milk protein polymorphisms and major constituents in Holstein-Friesian cows. *J. Dairy Sci.* 69:22-26.
- Ng-Kwai-Hang, K. F. and E. M. Kroeker. 1984. Rapid separation and quantification of major caseins and whey proteins of bovine milk by polyacrylamide gel electrophoresis. *J. Dairy Sci.* 67:3052-3056.
- Ng-Kwai-Hang, K. F., H. G. Monardes and J. F. Hayes. 1990. Association between genetic polymorphism of milk proteins and production traits during three lactations. *J. Dairy Sci.* 73:3414-3420.
- PATLQ. 1995. Rapport de Production. Programme d'Analyse des Troupeaux Laitiers du Québec.
- Rozzi, P., P. Serventi and S. Runchi. 1989. Effetto delle varianti di κ -caseina e β -latoglobulina sugli indici genetici produttivi di bovine di razza Frisone. *Sci. Techn. Latt. Cas.* 40:411-422.