Acta Agraria Kaposváriensis (2014) Vol 18 Supplement 1, 81-88.
Kaposvári Egyetem, Agrár- és Környezettudományi Kar, Kaposvár
Kaposvár University, Faculty of Agricultural and Environmental Sciences, Kaposvár

Effect of breed and dairy system on milk composition and udder health traits in multi-breed dairy herds

T. Bobbo, A. Cecchinato, C. Cipolat-Gotet, G. Stocco, G. Bittante
Department of Agronomy, Food, Natural resources, Animals and Environment
University of Padova, Agripolis, Viale dell'Università 16, 35020 Legnaro (PD), Italy

ABSTRACT

The aim of the present study was to investigate the effect of breed and dairy system on milk composition and udder health (UH) traits in multi-breed dairy herds. Individual milk samples (n=1,516) were collected from 41 multi-breed herds located in Trento province (in the North-East Italian Alps). Six breeds were involved: Brown Swiss (n=661), Holstein Friesian (n=473), Jersey (n=45), Simmental (n=158), Grey Alpine (n=75) and Rendena (n=104). Four different farming systems were identified: "Original Traditional" (lactating cows that are moved to highland pastures during summer; n=9), "Traditional without summer pastures" (n=11) "Traditional with silages" (n=2), and "Modern" (n=19). Analysis of variance was performed on milk composition and UH traits using the MIXED procedure of SAS. Orthogonal contrasts were estimated between least squares means of traits for the breed and the dairy system effects. Relevant differences have been highlighted between the six breeds regarding the milk composition traits, while breed differences for UH traits were negligible. The dairy system management revealed a limited influence on all considered traits.
(Keywords: milk composition traits, udder health traits, breed, dairy system, multi-breed herd)

INTRODUCTION

Increased milk production is one of the main dairy breeding goals worldwide dominating selection the last decades (*Meredith et al.*, 2012). However, new breeding goals have recently been identified, especially on milk composition, following the demands of a healthier human diet (*Boichard et al.*, 2012). Fat, protein and casein content are important traits for the milk and cheese industry while the fraction of milk used for cheese making is growing worldwide (*International Dairy Federation*, 2012). Milk urea nitrogen (MUN) is another interesting trait with remarkable environmental implications. Milk urea is synthesized as consequence of an imbalance between dietary nitrogen and energy in the rumen, and reflects inefficient protein synthesis. As the main non-protein source of nitrogen in milk, MUN reflects the efficiency of nitrogen utilization and the output of nitrogen to the environment. Among the functional traits**,** it is well known that udder health (UH) influence the qualitative and technological properties of milk. Somatic cell count (SCC) is commonly used as indicator trait of UH. Nevertheless, it has been recently reported that other traits such as lactose, pH, lactoferrin and minerals might be used as UH indicators (*Macciotta et al.*, 2012). Lactose concentration decreases during mastitis and its association with SCC has been widely studied (*Kitchen*, 1981). In addition, it has been found that mastitis markedly influences the ionic environment in milk. As a consequence of blood components moving into the milk, the pH may increase during mastitis (*Kitchen*, 1981). Finally, lactoferrin (an iron-binding glycoprotein which plays a key role as chemical barrier in defense mechanisms) concentration in milk is significantly associated with SCC (*Harmon et al*., 1975). An important question, though, before applying the new knowledge into practice, is to check whether there is a considerably source of variation of the aforementioned traits. To our knowledge, there are no studies on these traits in different breeds reared in multi-breed herds with different dairy system managements. Therefore, the aim of the present study was to investigate the effect of breed and dairy system on milk composition and UH traits in multi-breed dairy herds.

MATERIAL AND METHODS

Individual milk samples (n=1,516) were collected from 41 multi-breed herds located in Trentino region, Northern Italy, between March and December 2013. Six breeds were considered: Brown Swiss (BS, n=661), Holstein Friesian (HF, n=473), Jersey (Jer, n=45), Simmental (Si, n=158), Grey Alpine (GA, n=75) and Rendena (Ren, n=104). Herds were classified following the classification of Sturaro et al. (2013). Basically, four different farming systems were identified: "Original Traditional" (Orig-trad: lactating cows that are moved to highland pastures during summer; n=9), "Traditional without summer pastures" (Tr-nopast; n=11) "Traditional with silages" (Tr-si; n=2), and "Modern" (Mod; n=19). After collection, milk samples were refrigerated (4 °C) and processed within 24 hours from the collection. In the laboratory of the University of Trento individual milk subsamples were analyzed for protein, casein (%) and urea (mg/100 g) using a Milkoscan FT6000 (Foss, Hillerød, Denmark). In the laboratory of the University of Padova milk subsamples were analyzed for fat and lactose (%) using a MilkoScan FT2 (Foss, Hillerød, Denmark). SCC was obtained from a Fossomatic Minor (Foss, Hillerød, Denmark) and log-transformed to somatic cell score (SCS). Milk pH was obtained using a Crison Basic 25 electrode (Crison Instruments SA, Barcelona, Spain). Lactoferrin content (%) was measured by HPLC (High Performance Liquid Chromatography) analysis following the method of *Maurmayr et al*. (2013).

Analysis of variance was performed on milk composition and UH traits using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with the following linear model:

$$y_{ijklmn} = \mu + DIM_i + Parity_j + Breed_k + Dairy\ system_l + Herd_m\ (dairy\ system)_l + e_{ijklmn},$$

where y_{ijklmn} is the dependent variable; μ is the overall mean; DIM_i is the fixed effect of the *i*th class of days in milk (*i*=11 classes of 30-d intervals, from 5 to >305 d); $Parity_j$ is the fixed effect of the *j*th parity (*j*=1 to ≥6); $Breed_k$ is the fixed effect of the *k*th breed (*k*=BS, HF, Jer, Si, GA and Ren); Dairy $system_l$ is the fixed effect of the *l*th class of dairy system (*l*=Orig-trad, Tr-nopast, Tr-si and Mod); $Herd_m$ (dairy $system)_l$ is the random effect of the *m*th herd (*m*=1 to 41) within the *l*th class of dairy system; e_{ijklmn} is the random residual ~ N (0, σ_e^2). Orthogonal contrasts were estimated between least-squares means (LSMs) of traits for the breed effect: a) specialized (BS, HF and Jer) vs dual purpose breeds (Si, GA and Ren); within specialized, b) BS+HF vs Jer and c) BS vs HF; within dual purpose, d) Si vs GA+Ren and e) GA vs Ren. Orthogonal contrasts were estimated also between LSMs of traits for the dairy system effect: a) traditional (Orig-trad, Tr-nopast and Tr-si) vs modern management; within traditional herds, b) Orig-trad+Tr-nopast vs Tr-si and c) Orig-trad vs Tr-nopast.

RESULTS AND DISCUSSION

Descriptive statistics for milk production, composition and UH traits are shown in *Table 1*. All traits exhibited high variability basically attributable to the breed differences. The results from ANOVA for the aforementioned traits are reported in *Table 2*. DIM and parity effects were important source of variation (P<0.001) for all the investigated traits, except for a negligible effect of parity on fat. In this study, particular interest was attributed to the breed effect, which is important in explaining the variability for all the analyzed traits, in particular for all milk composition traits and, within UH traits, for the lactose (P<0.001).

Table 1

Descriptive statistics of single test-day milk yield, composition and udder health traits[1]

Trait[2]	N	Mean	SD	P 1	P 99
Milk yield, kg/d	1451	24.32	9.15	6.00	49.40
Milk composition					
Fat, %	1495	4.22	0.92	1.88	7.12
Protein, %	1221	3.61	0.47	2.66	4.82
Casein, %	1224	2.84	0.38	2.10	3.80
Casein number	1224	0.78	0.01	0.75	0.81
MUN, mg/100 g	1224	25.0	9.6	7.5	49.0
Udder health					
Lactose, %	1510	4.97	0.29	4.10	5.52
pH	1510	6.51	0.10	6.27	6.74
SCC (10^3/mL)	1509	221	397	9	1,968
SCS, U	1509	2.84	1.86	-0.47	7.30
Lactoferrin, g/L	1492	0.097	0.052	0.026	0.236

[1]P1 = 1st percentile; P99 = 99th percentile
[2] MUN = milk urea nitrogen; SCS = log2 (SCC * 1,000/100,000) + 3

Our findings confirmed the results reported by *De Marchi et al*. (2007), who investigated differences in milk composition and coagulation traits in 5 dairy cattle breeds (BS, HF, Si, GA and Ren) sampled in mono-breed herds located in the same province considered for this study. In particular, excluding the Jer breed considered only in this paper, in both studies the milk of HF breed contained lower protein content (3.19% in *De Marchi et al.* (2007) vs 3.36% in our study), while the higher protein content was observed in BS (3.48% in *De Marchi et al*. (2007) vs 3.69% in our study).

Moreover, in the case of fat content, in both experiments a lower mean was observed in Ren (3.39% in *De Marchi et al*. (2007) vs 3.73% in our study) and a higher mean in Si (3.82% in De Marchi et al. (2007) vs 4.28% in our study). The effect of dairy system was negligible in explaining the variation of the former traits, except for protein and casein content (P<0.05) and for MUN (P<0.001). The highly significance of dairy system for MUN was expected as urea synthesis is related to dietary nitrogen. For this trait, in fact, the proportion of variance explained by herd/test date was approximately 73% (*Table 2*).

Table 2

Results from ANOVA (F-value and significance) for single test-day milk yield, composition and udder health traits

Trait[3]	DIM	Parity	Breed	RMSE[1]	Dairy system	HTD, %[2]
Milk yield, kg/d	64.44***	28.19***	40.34***	5.05	2.48^{ns}	54.75
Milk composition						
Fat, %	19.64***	1.06^{ns}	33.3***	0.76	1.37^{ns}	12.17
Protein, %	74.05***	6.2***	38.33***	0.30	3.43*	25.00
Casein, %	61.53***	7.71***	29.94***	0.25	3.31*	24.24
Casein number	8.35***	15.47***	4.32***	0.01	1.84^{ns}	0.00
MUN, mg/100 g	3.88***	4.44***	7.90***	4.27	7.34***	73.05
Udder health						
Lactose, %	18.41***	20.64***	4.83***	0.25	1.07^{ns}	13.79
pH	7.06***	9.29***	3.43**	0.07	1.84^{ns}	0.00
SCS, U	17.68***	13.05***	3.47**	1.62	0.12^{ns}	12.65
Lactoferrin, g/L	4.76***	4.27***	3.04**	0.05	1.52^{ns}	0.00

[1]RMSE= root mean square error

[2]HTD, %= Herd/Test day effect expressed as proportion of variance explained by herd/test date calculated by dividing the corresponding variance component by the total variance.

[3]MUN = milk urea nitrogen; SCS = log2 (SCC * 1,000/100,000) + 3

ns= not significant; *P<0.05; **P<0.01; ***P<0.001

LSMs and orthogonal contrasts p-values of milk yield, composition and UH traits across breed and dairy system are reported in *Tables 3* and *4*, respectively.

Between the six breeds, HF displayed the highest milk yield (MY) (27.45 kg/d) and the lowest protein (3.36%) and casein (2.64%) content, while Jer shows the lowest MY (17.27 kg/d) and the highest fat (5.65%), protein (3.93%) and casein (3.10%) content. Specialized breeds reported higher fat, protein and casein percentages in comparison with the dual purpose breeds, while no significant differences was observed for MY, casein number and urea. Within the specialized breeds, there were relevant differences in almost all milk composition traits between BS and HF. With respect to MUN, a significant difference has been observed between BS and HF. We can assume that, on equal diet (BS and HF were mostly reared in the same multi-breed herds with a modern dairy system management), these two breeds have a different metabolism.

Table 3

Least squares means of single test-day milk yield, composition traits across breed and dairy system[1]

	MY, kg/d	Fat, %	Protein, %	Casein, %	Casein number	MUN, mg/100 g
Breed						
Brown Swiss (BS)	24.30	4.32	3.69	2.88	0.78	30.16
Holstein Friesian (HF)	27.45	4.04	3.36	2.64	0.78	27.91
Jersey (Jer)	17.27	5.65	3.93	3.10	0.79	28.44
Simmental (Si)	24.38	4.28	3.53	2.77	0.78	28.85
Grey Alpine (GA)	19.86	3.98	3.64	2.86	0.79	28.96
Rendena (Ren)	22.95	3.73	3.38	2.65	0.79	28.49
Contrast, p-value						
BS+HF+Jer vs Si+GA+Ren	0.255	<0.001	<0.001	<0.001	0.955	0.905
BS+HF vs Jer	<0.001	<0.001	<0.001	<0.001	0.004	0.651
BS vs HF	<0.001	<0.001	<0.001	<0.001	0.304	<0.001
Si vs GA+Ren	<0.001	<0.001	0.619	0.675	0.245	0.842
GA vs Ren	0.003	0.074	<0.001	<0.001	0.894	0.594
Dairy system						
Original traditional (Orig-trad)	18.37	4.28	3.57	2.79	0.78	34.56
Traditional no pasture (Tr-nopast)	21.47	4.15	3.38	2.67	0.79	27.83
Traditional with silages (Tr-si)	27.10	4.54	3.78	2.96	0.78	31.83
Modern (Mod)	23.86	4.36	3.62	2.85	0.79	20.98
Contrast, p-value						
Tr vs Mod	0.453	0.767	0.584	0.455	0.675	0.001
Orig-trad+Tr-nopast vs Tr-si	0.095	0.166	0.030	0.034	0.441	0.906
Orig-trad vs Tr-nopast	0.232	0.391	0.064	0.101	0.034	0.083

[1]MY = milk yield; MUN = milk urea nitrogen

HF, a breed selected for milk production, presented a lower level of MUN in the milk, in comparison with BS. Within the dual purpose breeds, Si, a large-sized widespread breed, reported higher MY and fat percentages in comparison with GA and Ren, small-sized local breeds. Considering the four dairy system classes, Tr-si showed the highest values of MY (27.10 kg/d), fat (4.54%), protein (3.78%) and casein (2.96%). The lowest value of urea synthesis has been found in modern dairy management (20.98 mg/100 g), while Orig-trad showed the highest value (34.56 mg/100 g). For protein, casein and casein number only one contrast exhibited a significant p-value (Orig-trad+Tr-nopast vs Tr-si for protein and casein, Orig-trad vs Tr-nopast for casein number).

Table 4

Least squares means of udder health traits across breed and dairy system[1]

	Lactose, %	pH	SCS, U	Lactoferrin, g/L
Breed				
Brown Swiss (BS)	4.95	6.52	3.03	0.087
Holstein Friesian (HF)	4.96	6.52	3.23	0.097
Jersey (Jer)	4.83	6.51	2.85	0.093
Simmental (Si)	4.94	6.50	2.50	0.104
Grey Alpine (GA)	5.01	6.54	2.83	0.100
Rendena (Ren)	5.07	6.52	2.92	0.091
Contrast, p-value				
BS+HF+Jer vs Si+GA+Ren	<0.001	0.945	0.079	0.227
BS+HF vs Jer	0.005	0.334	0.349	0.969
BS vs HF	0.488	0.984	0.097	0.004
Si vs GA+Ren	0.003	0.004	0.084	0.189
GA vs Ren	0.182	0.068	0.760	0.332
Dairy system				
Original traditional (Orig-trad)	4.97	6.50	2.79	0.082
Traditional no pasture (Tr-nopast)	4.99	6.47	2.82	0.088
Traditional with silages (Tr-si)	4.94	6.58	3.09	0.114
Modern (Mod)	4.93	6.52	2.88	0.097
Contrast, p-value				
Tr vs Mod	0.267	0.856	0.920	0.781
Orig-trad+Tr-nopast vs Tr-si	0.573	0.084	0.581	0.103
Orig-trad vs Tr-nopast	0.572	0.425	0.917	0.558

[1]SCS = log2 (SCC * 1,000/100,000) + 3

Differences between LSMs of dairy system for UH traits were negligible. The milk of breeds with higher MY (BS, HF and Si) presented low lactose content (4.95, 4.96 and 4.94%, respectively). However, we found the lowest value of lactose (4.83%) in milk from Jer, a small breed with low milk production but high milk quality. Probably, the milk of this breed is characterized by a higher mineral content. For pH and lactoferrin, one contrast (Si vs GA+Ren for pH and BS vs HF for lactoferrin) reported a relevant p-value ($P<0.01$). Not relevant differences between breeds have been observed for the SCS trait. Finally, the different dairy system management seems to have a negligible effect on UH traits.

CONCLUSIONS

In conclusion, relevant differences have been highlighted between the six breeds regarding the milk composition traits, while breed differences for UH traits were negligible. The dairy system management revealed a limited influence on all considered traits. However, the average values of milk components have shown some differences: in particular, Tr-si produces milk with higher fat, protein and casein content, but also with higher content in somatic cells.

ACKNOWLEDGEMENTS

The financial support of the Autonomous Province of Trento is gratefully acknowledged.

REFERENCES

Boichard, D., Brochard, M. (2012). New phenotypes for new breeding goals in dairy cattle. Animal, 6(04). 544-550.

De Marchi, M., Dal Zotto, R., Cassandro, M., Bittante, G. (2007). Milk coagulation ability of five dairy cattle breeds. Journal of Dairy Science, 90. 3986-3992.

Harmon, R. J., Schanbacher, F. L., Ferguson, L. C., Smith, K. L. (1975). Concentration of lactoferrin in milk of normal lactating cows and changes occurring during mastitis. American Journal of Veterinary Research, 36. 1001–1007.

Kitchen, B. (1981). Review of the progress of dairy science: Bovine mastitis: Milk compositional changes and related diagnostic tests. Journal of Dairy Research, 48. 167–188.

International Dairy Federation. (2012). The world dairy situation. Bulletin 458/2012. International Dairy Federation, Brussels, Belgium.

Macciotta, N.P.P., Cecchinato, A., Mele, M., Bittante, G. (2012). Use of multivariate factor analysis to define new indicator variables for milk composition and coagulation properties in Brown Swiss cows. Journal of Dairy Science, 95(12). 7346-7354.

Maurmayr, A., Cecchinato, A., Grigoletto, L., Bittante, G. (2013). Detection and quantification of αS1-, αS2-, β-, κ-casein, α-lactalbumin, β-lactoglobulin and lactoferrin in bovine milk by Reverse-Phase High-Performance Liquid Chromatography. Agriculturae Conspectus Scientificus, Vol. 78 No. 3.

Meredith, B.K., Kearney, F.J., Finlay, E.K., Bradley, D.G., Fahey, A.G., Berry, D.P., Lynn, D.J. (2012). Genome-wide associations for milk production and somatic cell score in Holstein-Friesian cattle in Ireland. BMC Genetics, 13. 21-32.

Sturaro, E., Marchiori, E., Cocca, G., Penasa, M., Ramanzin, M., Bittante, G. (2013). Dairy systems in mountainous areas: Farm animal biodiversity, milk production and destination, and land use. Livestock Science, 158. 157-168.

Viguier, C., Arora, S., Gilmartin, N., Welbeck, K., O'Kennedy, R. (2009). Mastitis detection: current trends and future perspectives. Trends in Biotechnology, 27. 8-10.

Corresponding author:

Tania Bobbo
Department of Agronomy, Food, Natural resources, Animals and Environment
University of Padova, Agripolis
Viale dell'Università 16, 35020 Legnaro (PD), Italy
E-mail: tania.bobbo@studenti.unipd.it