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A preliminary investigation into genotype x environment interaction in South African Holstein cattle for reproduction and production traits

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Abstract

The purpose of the study was to investigate a possible genotype by environment interaction in first calf South African Holstein cows for both production and reproduction traits. Data from 100 975 cows on a total mixed ration (TMR) and 22 083 pasture based cows were used. These cows were the progeny of 4 391 sires and 84 935 dams produced over a period of 11 generations. Traits analysed were milk production (corrected to a 305-day equivalent) and age at first calving (AFC). Both were recorded over a period of 30 years from 1980 - 2010. Production or AFC in each environment (TMR vs. pasture) was treated as a separate trait. Bivariate analyses, fitting an animal model using the ASREML software, were used to obtain genetic correlations between the traits measured in each environment. The fixed factors included were a concatenation of breeder-keeper-year for both milk production and AFC and age at first calving which was fitted as a linear regression for milk production. The random part consisted of the direct additive effects only. The genetic correlation for milk production measured in the two different environments was 0.90 (0.027) and that of age at first calving 0.28 (0.12). The heritability estimates for milk production were 0.23 (0.008) under the TMR system and 0.32 (0.015) for the pasture based system, while the estimates for AFC were 0.063 (0.005) and 0.055 (0.009), respectively. The rather large-scale effect in the heritability (0.23 → 0.32), as well as the correlation of less than one for milk production between the two environments, indicates that a G x E may exist. However, the low genetic correlation between the two environments for AFC is much more real and indicates that G x E should be taken into account when sire selection is performed.

Keywords: Age at first calving, milk production, total mixed ration, pasture
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Introduction

Genotype x environment interaction (G x E) in dairy cattle is a contentious issue that is usually ignored in genetic evaluations. It can, however, play a significant role in the accuracy of breeding values in different environments, if it exists, with a negative impact on genetic response when it is ignored. In South Africa two main production environments exist. The majority of cows in milk recording are kept under a total mixed ration (TMR) system. There are, however, a significant number of herds that utilize a pasture-base system for milk production. Currently, many bulls are used in both these systems without regard of any possible change of rank that may occur between these systems if a genotype x environment interaction exists.

Genotype by environment interaction can be described by inclusion of an interaction term in the traditional quantitative genetic model. Another approach is to define the phenotypic expression in various environments, as separate traits and estimate the genetic correlation between those traits.

The purpose of the study was thus to investigate a possible genotype by environment interaction in first calf South African Holstein cows for both production and reproduction traits by treating the traits in each environment as separate traits.

Materials & Methods

Data from 100 975 cows on a TMR system and 22 083 pasture based cows were used in the analysis. These cows were the progeny of 4391 sires and 84 935 dams produced over a period of 11 generations, in 277 herds. Traits analysed were first lactation milk production (corrected to a 305-day equivalent) and age at first calving (AFC). Both were recorded over a period of 30 years from 1980 - 2010.

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Table 1 Descriptive statistics of data used after editing for the first lactation milk production and age at first calving (AFC) in the analysis

Trait	n	Mean ± SD	Minimum	Maximum	CV%
Milk production (kg)					
Total mixed ration	100 975	8221 ± 2452.0	126	17 510	29.83
Pasture	22 083	6366 ± 1279.0	1 456	11 430	20.09
AFC (days)					
Total mixed ration	100 975	820.4 ± 115.7	463	1 325	14.10
Pasture	22 083	857.9 ± 110.7	444	3 449	12.90

n = number of records; SD = standard deviation; CV% = coefficient of variation.

Production or AFC in each environment (TMR vs. pasture) was treated as separate traits. A concatenation of breeder-keeper-year was fitted as a fixed effect for both production and AFC, while age at first calving was fitted as a linear regression for milk production. Two trait animal models were fitted, which allowed the calculation of relevant genetic correlations between traits measured in each environment, together with their appropriate standard errors. This was obtained using the ASREML program (Gilmour *et al*., 2009).

The bivariate model used in the estimation of genetic (co)variances for both milk production and AFC were:

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} X_1\beta_1 \\ X_2\beta_2 \end{bmatrix} + \begin{bmatrix} Z_1g_1 \\ Z_2g_2 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

Where Y_i is a $n \times 1$ vector of records for the i^{th} trait; i = 1 to 2 for milk production on a TMR system and milk production in a pasture system or AFC on a TMR system and AFC in a pasture system. X_i is a $n \times p$ incidence matrix that relates data to the unknown vector of location parameters β_i. The vector β contains breeder-keeper-year as a fixed effect for both milk production and AFC and age at first calving as a linear regression for milk production. The incidence matrix Z_i relating to unknown random vectors of the direct breeding value g_i (i = 1 to 2) to Y_i. The unknown vector e_i contains the random residuals due to environmental effects specific to individual records. The random genetic effects were assumed to have a mean of zero and variances (VARg):

$$\text{VARg}\begin{bmatrix} g_1 \\ g_2 \end{bmatrix} = \begin{bmatrix} A\sigma^2g_1 & A\sigma g_1g_2 \\ A\sigma g_2g_1 & A\sigma^2g_2 \end{bmatrix}$$

where A represents the numerator relationship matrix with rank equal to the number of animals in the pedigree (n = 213 089) used in the analysis. The random residual effects were assumed to have a mean of zero and variances (VARe).

$$\text{VARe}\begin{bmatrix} e_1 \\ e_2 \end{bmatrix} = \begin{bmatrix} E\sigma^2e_1 & E\sigma e_1e_2 \\ E\sigma e_2e_1 & E\sigma^2e_2 \end{bmatrix}$$

where E represents an identity matrix with rank equal to the number of animals with records (n = 123 058).

Results and Discussion

Statistics describing first lactation milk production (kg) and age at first calving (AFC) (days) in the two different environments are presented in Table 1. Milk production differed between the two environments. A first-lactating Holstein cow on a TMR feeding system produced on average 1855 kg more milk per 305-day lactation period than her counterpart under a pasture feeding system. For age of first calving the difference between the two production systems was 37.5 days in favour of the TMR system.

Parameter estimates for production and reproduction traits measured in the two different environments are presented in Table 2. In the case of milk production, heritability estimates obtained from a wide range of dairy populations ranged from 0.17 to 0.29 (Weller & Ezra, 2004; Mostert *et al*., 2006; Maiwashe *et al*., 2008; De Ponte Bouwer *et al*., 2013). The estimate of the present study for TMR (0.23) generally accords well with the range of literature values cited. The corresponding estimate of 0.32 for the population from the pasture based feeding system is higher than these respective values.

The heritability estimates for AFC were much lower than those in previous reports (0.22; Allaire & Lin, 1980), (0.16; Moore *et al*., 1992), (0.38; Ojango & Pollott, 2001) but similar to estimates less than 0.10 (Moore *et al*., 1991; Mäntysaari *et al*., 2002; Nilforooshan & Edriss, 2004) and even as low as 0.02 (VanRaden & Klaaskate, 1993).

Table 2 Estimates of (co)variance components and ratios (SE in brackets), as well as direct heritability (in bold on the diagonal), genetic correlations (below the diagonal) and phenotypic correlations (above the diagonal) obtained from the two-trait analysis

Parameters	**Milk production**		**Age at first calving**	
	Total mixed ration	**Pastures**	**Total mixed ration**	**Pastures**
Variances				
Direct additive	360 270	274 361	438.45	452.79
Error	1 179 070	571 718	6 514.28	7 769.35
Phenotypic	1 539 340	846 079	6 952.70	8 222.10
(Co) variance ratios				
Milk production				
Total mixed ration	0.23 (0.008)	0.90 (0.027)		
Pastures	282 487	0.32 (0.015)		
Age at first calving				
Total mixed ration			0.063 (0.005)	0.28 (0.12)
Pastures			126.49	0.055 (0.009)

The genetic correlation for first lactation milk production measured in the two different environments was 0.90 (0.027) and that of age at first calving 0.28 (0.12). Veerkamp *et al*. (1994) reported no interaction between genotype and feeding system for milk production traits. The value of 0.90 was high compared with the estimate of 0.60 between the 305-d milk yields of Luxembourg and Tunisian Holstein populations (Hammami *et al*., 2009). Weigel *et al.* (2001) found high genetic correlations (>0.80) between milk yields across 17 Interbull country members. The reported estimates were higher than 0.90 between countries with predominantly grazing systems (i.e. Ireland, Australia, New Zealand). Genetic correlations were also higher than 0.91 between countries with high milk production (USA, Canada, Belgium, The Netherlands and Italy). Correlations between remaining Interbull members ranged between 0.8 and 0.9. On the other hand, studies on G x E between countries with different climatic conditions and production systems (Stanton *et al*., 1991; Costa *et al*., 2000; Ojango & Pollott, 2002) are limited. In these studies, genetic correlations between countries suggest the existence of G × E for milk yield in Holsteins. In general most of the estimates reported were high (>0.80) showing little or no evidence for a significant G × E in milk production. Almost all the within-country analyses, according to a review by Hammani *et al.* (2009), reported only a scaling effect for milk yield with large heterogeneity of variances and in some case heterogeneity of heritability estimates was observed.

Mee (2012), in a review on reproductive issues arising from different management systems (zero grazing and pasture based), reported variable results for genotype x environment interaction in reproduction traits for dairy cattle. Studies in Brazil and Columbia (Ceron-Munoz *et al*., 2004), the Netherlands (Calus *et al*., 2005), Australia (Fulkerson *et al*., 2008) and in the UK (Haskell *et al*., 2007; Strandberg *et al*., 2009) found G x E interactions when reproduction between different herd management systems were compared. Other studies on reproduction performance under different production environments in the UK (Pryce *et al*., 1999), Canada (Boettcher *et al*., 2003), Ireland (Buckley *et al*., 2003), the USA (Kearney *et al*., 2004) and

Australia (Haile-Mariam *et al*., 2008), in contrast, found no G x E. This, according to Mee (2012) reflects the variety of herd management systems, the variation in methods used to describe reproductive performance and the limitations of some study designs.

Conclusions

The rather large scale effect in the heritability (0.23 → 0.32) as well as the correlation of less than one for milk production between the two environments indicates that a G x E may exist. However, the low genetic correlation between the two environments for AFC is much more real and indicates that G x E should be taken into account when sire selection is done. Breeders should select animals within environmental conditions, comparable to where candidate animals are intended to perform.

References

Allaire, F.R. & Lin, C.Y., 1980. Heritability of age at first calving. J. Dairy Sci. 63,171-173.

Boettcher, P.J., Fatehi, J. & Schutz, M.M., 2003. Genotype x environment interactions in conventional versus pasture-based dairies in Canada. J. Dairy Sci. 86, 383-389.

Buckley, F., Berry, D.P. & Dillon, P., 2003. Evidence of genotype by environment interaction for fertility in dairy cattle. Reprod. Domest. Anim. 38, 319.

Calus, M.P.L., Windig, J.J. & Veerkamp, R.F., 2005. Associations among descriptors of herd management and phenotypic and genetic levels of health and fertility. J. Dairy Sci. 88, 2178-2189.

Ceron-Munoz, M.F., Tonhati, H., Costa, C.N., Maldonado-Estrada, J. & Rojas-Sarmiento, D., 2004. Genotype x environment interaction for age at first calving in Brazilian and Colombian Holsteins. J. Dairy Sci. 87, 2455-2458.

Costa, C.N., Blake, R.W., Pollak, E.J., Oltenacu, P.A., Quaas, R.L. & Searle, S.R., 2000. Genetic analysis of Holstein cattle populations in Brazil and the United States. J. Dairy Sci. 83, 2963-2974.

De Ponte Bouwer, P., Mostert, B.E. & Visser, C., 2013. Genetic parameters for production traits and somatic cell score of the SA Dairy Swiss population. S. Afr. J. Anim. Sci. 43, 113-122.

Fulkerson, W.J., Davison, T.M., Garcia, S.C., Hough, G., Goddard, M.E., Dobos, R. & Blockey, M., 2008. Holstein-Friesian dairy cows under a predominantly grazing system: Interaction between genotype and environment. J. Dairy Sci. 91, 826-83.

Gilmour, A.R., Gogel, B.J., Cullis, B.R. & Thompson, R., 2009 ASReml User Guide Release 3.0 VSN International Ltd, Hemel Hempstead, HP1 1ES, UK www.vsni.co.uk

Haile-Mariam, M., Carrick, M.J. & Goddard, M.E., 2008. Genotype by environment interaction for fertility, survival, and milk production traits in Australian dairy cattle. J. Dairy Sci. 91, 4840-4853.

Hammami, H., Rekik, B., Soyeurt, H., Bastin, C., Stoll, J. & Gengler, N., 2009. Genotype × environment interaction for milk yield in Holsteins using Luxembourg and Tunisian populations. J. Dairy Sci. 91, 3661-3671.

Haskell, M.J., Brotherstone, S., Lawrence, A.B. & White, I.M.S., 2007. Characterisation of the dairy environment in Great Britain and the effect of the farm environment on cow life span. J. Dairy Sci. 90, 5316-5323.

Kearney, J.F., Schutz, M.M. & Boettcher, P.J., 2004: Genotype x environment interaction for grazing vs. confinement. II. Health and reproduction traits. J. Dairy Sci. 87, 510-516.

Maiwashe, A., Nephawe, K.A. & Theron, H.E., 2008. Estimates of genetic parameters and effects of inbreeding on milk yield and composition in South African Jersey cows. S. Afr. J. Anim. Sci. 38, 119-125.

Mantysaari, P., Ojala, M. & Mäntysaari. E.A., 2002. Measures of before and after breeding daily gains of dairy replacement heifers and their relationship with first lactation milk production traits. Livest. Prod. Sci. 75, 313-322.

Mee, J.F., 2012. Reproductive issues arising from different management systems in the dairy industry. Reprod. Domest. Anim. 47 Suppl. 5, 42-50.

Moore, R.K., Kennedy, P.P., Schaeffer, L.R. & Moxley. J.E., 1991. Relationships between age and body weight at calving and production in first lactation Ayrshires and Holsteins. J. Dairy Sci. 74, 269-278.

Moore, R.K., Kennedy, P.P., Schaeffer, L.R. & Moxley. J.E., 1992. Relationships between age and body weight at calving, feed intake, production, days open and selection indexes in Ayrshires and Holsteins. J. Dairy Sci. 75, 294-306.

Mostert, B.E., Theron, H.E., Kanfer, F.H.J. & Van Marle-Köster, E., 2006. Comparison of breeding values and genetic trends for production traits estimated by a lactation model and a fixed regression test-day model. S. Afr. J. Anim. Sci. 36, 71-78.

Nilforooshan, M.A. & Edriss, M.A., 2004. Effect of age at first calving on some productive and longevity traits in Iranian Holsteins of the Isfahan province. J. Dairy Sci. 87, 2130-2135.

Ojango, J.M.K. & Pollott, G.E., 2001. Genetics of milk yield and fertility traits in Holstein-Friesian cattle on large-scale Kenyan farms. J. Anim. Sci. 79, 1742-1750.

Ojango, J.M.K. & Pollott, G.E., 2002. The relationship between Holstein bull breeding values for milk yield derived in both the UK and Kenya. Livest. Prod. Sci. 74, 1-12.

Pryce, J.E., Nielsen, B.L., Veerkamp, R.F. & Simm, G., 1999. Genotype and feeding system effects and interactions for health and fertility traits in dairy cattle. Livest. Prod. Sci. 57, 193-220.

Strandberg, E., Brotherstone, S., Wall, E. & Coffey, M.P., 2009. Genotype by environment interaction for first-lactation female fertility traits in UK dairy cattle. J. Dairy Sci. 92, 3437-3446.

Stanton, T.L., Blake, R.W., Quaas, R.L., Van Vleck, L.D. & Carabaño, M.J., 1991. Genotype by environment interaction for Holstein milk yield in Colombia, Mexico and Puerto Rico. J. Dairy Sci. 74, 1700-1714.

VanRaden, P.M. & Klaaskate, E.J.H., 1993. Genetic evaluation of length of productive life including predicted longevity of live cows. J. Dairy Sci. 76, 2758-2764.

Veerkamp, R.F., Simm, G. & Oldham, J.D., 1994. Effects of interaction between genotype and feeding system on milk production, feed intake, efficiency and body tissue mobilization in dairy cows. Livest. Prod. Sci., 39, 229-241

Weigel, K.A., Rekaya, R., Zwald, N.R. & Fikse, W.F., 2001. International genetic evaluation of dairy sires using a multipletrait model with individual animal performance records. J. Dairy Sci. 84, 2789-2795.

Weller, J.I. & Ezra, E., 2004. Genetic analysis of the Israeli Holstein dairy cattle population for production and non-production traits with a multitrait animal model. J. Dairy Sci. 87, 1519-1527.