Genetic parameter estimates for type traits in the South African Jersey breed

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Abstract

Known environmental effects influencing type trait scores in South African Jersey cattle were identified. Variance components and heritabilities were estimated for these traits as well as genetic correlations among them and with production traits. Heritability estimates were generally low to medium. It is suggested that hoof and leg traits be excluded due to low estimated heritabilities and/or coefficients of variation. Genetic correlation estimates suggested that selection for production yield should improve most type traits and *vice versa*. Estimation of breeding values and fitting a multiple trait model is suggested.

Key words: Genetic parameters, Jersey cattle, type traits, variance components.
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Introduction

Type traits have been classified and recorded on an organised basis for South African Jerseys since 1984. The practical procedure initiated by Jersey SA has been revised and the next logical step is to investigate the possibility of providing estimated breeding values for the 13 type traits identified and described by Van Niekerk *et al*. (1998). To enable the application of mixed model methodology, the applicable non-genetic factors must be identified to facilitate the construction of the fixed part of the operational model. Also, the applicable genetic (co)variances need to be known, at least to proportionality, as measured by the usual genetic parameters (heritability and correlation). The purpose of this study was to identify the significant non-genetic factors influencing type traits and to estimate the applicable genetic parameters for and among type and production traits.

Material and Methods

Approximately 36 000 records were available, which were reduced to 9 447 after editing. The criteria for records to be included in analysis were as follows:

(i) Lactation length: 240 – 300 days
(ii) Complete pedigree information (sire, dam and birth date)
(iii) Animals had to be classified during their first lactation and have an official first lactation
(iv) Age at first calving: 17 months < X < 36 months
(v) Age at classification: 18 months < X < 40 months
(vi) Five animals in a contemporary group.

The type traits currently being scored in the South African Jersey, and used in this study, are: wither height (WH), strength (ST), dairy form (DF), rump angle (RA), thurl width (TW), rear legs side-view (RL), hoof inclination (FA), fore udder attachment (FUA), rear udder height (RUH), rear udder width (RUW), udder cleft (UC), udder depth (UD) and teat placement (TP). For a complete description of the data and traits see Van Niekerk (1999).

To identify the effects to be included in the fixed part of the model, an analysis of variance was performed on a concatenation of herd, birth year, calving year and season of calving (HYYS), classifier, classification year, classification month, region, age at classification and stage of lactation. Only fixed effects identified as significant ($P \leq 0.10$), were included in the model and differed slightly for some traits. A summary of the effects included in the final models is presented in Table 1.

Table 1 Effects included in models

Trait	Herd/ Birth year/ Calving year/ Season	Classifier	Classification month	Classification year	Effects Region	Calving age	Stage of Lactation	R^2	Model
WH	+	+	+	+	+	+	+	0.42	1
ST	+	+	+	+	+	+	+	0.48	1
DF	+	+	+	+	-	+	-	0.32	2
RA	+	+	-	+	-	+	+	0.24	3
TW	+	+	+	+	-	+	+	0.36	4
RL	+	+	+	+	+	-	+	0.39	5
FA	+	+	+	+	+	-	-	0.33	6
FUA	+	+	+	+	-	+	+	0.41	4
RUH	+	+	+	+	+	+	+	0.43	1
RUW	+	+	+	+	+	+	+	0.41	1
UC	+	+	+	+	+	+	+	0.38	1
UD	+	+	+	+	-	+	+	0.47	4
TP	+	+	+	+	+	+	+	0.36	1

(+) Included in model; (-) Excluded from model

Taking the significant effects shown in Table 1 into consideration, model one (the saturated model) for WH, ST, RUH, RUW, UC and TP was fitted as:

$$Y_{ijklm} = \mu + HYYS_i + c_j + cm_k + cy_l + r_m + b_1 A + b_2 ST + e_{ijklm}$$

Where:

Y_{ijklm} = an observation on the trait considered
μ = overall mean,
$HYYS_i$ = the fixed effect of the i-th herd/year of birth/year of calving/season of calving (i = 1,...,987),
C_j = the fixed effect of the j-th classifier (j = 10, 14, 15, 16, 18, 20, 23, 24, 28, 30, 33, 50, 51, 61, 63, 64, 68),
cm_k = the fixed effect of the k-th month of classification (k = 1,...,12),
cy_l = the fixed effect of the l-th year of classification (l = 85,...,96),
r_m = the fixed effect of the m-th region (m = 1,..., 5, 7, 8),
b_1 A = linear regression of the deviation from the mean on age at first calving,
b_2 ST = linear regression of the deviation from the mean on stage of lactation at classification and
e_{ijklm} = random error associated with each record

The model that was fitted for the production traits was as follows:

$$Y_{ijklm} = \mu + HYYS_i + r_m + b_1 A + b_3 D + e_{ijklm}$$

b_3 D = linear regression of the deviation from the mean on length of lactation (in days)

The DFREML programme of Meyer (1995) was used to estimate heritabilities, phenotypic and genetic correlations among the 13 type traits and the three production traits (kilogram milk, butterfat and protein). Since computer capacity was a limitation, traits were analysed two at a time.
The following linear model was fitted:

$$y = Xb + Za + e$$

Where:

y = vector of records;
b = vector of fixed effects;
a = vector of additive genetic effects;
X, Z = incidence matrix which relates an observation to the fixed and random effects;
e = random error associated with each record.

Analysing traits two at a time led to 13 different heritability estimates for each trait. The weighted mean heritability and standard error estimates, which are the estimates supplied, were calculated using the method suggested by Koots *et al*. (1994).

Results and Discussion

The means, standard deviations and coefficient of variation for the 13 type and three production traits are presented in Table 2.

Table 2 Mean, standard deviation and coefficient of variation of type and production traits

Trait	Mean	Standard Deviation	Coefficient of Variation
Wither height	4.88	0.80	16.31
Strength	5.17	0.96	18.57
Dairy form	6.36	0.87	13.68
Rump angle	5.47	0.72	13.07
Thurl width	5.30	0.85	15.99
Rear legs side-view	5.52	0.67	12.17
Hoof inclination	4.78	0.77	16.03
Fore udder attachment	6.23	1.02	16.33
Rear udder height	6.08	0.97	15.97
Rear udder width	5.45	1.12	20.47
Udder cleft	6.00	0.92	15.32
Udder depth	6.70	0.78	11.57
Teat placement	4.61	0.95	20.50
Milk	4240.67	1078.68	25.44
Butterfat	190.60	49.32	25.88
Protein	157.11	38.56	24.54

The heritability estimates obtained for the 13 type traits are presented in Table 3. For comparison, estimates from other studies are also provided.

Table 3 Heritability estimates for type traits

Trait	Present study	SE	1	2	Other 3	Studies 4	5	6
Wither height	0.32	0.053	0.40	0.42	0.41	0.44	0.42	0.52
Strength	0.23	0.055	0.26	-	0.24	-	0.29	0.29
Dairy form	0.27	0.055	0.28	0.27	0.23	0.21	0.28	0.24
Rump angle	0.22	0.056	0.31	0.29	0.26	0.33	0.28	0.32
Thurl width	0.17	0.057	0.23	0.32	0.20	0.21	0.26	0.27
Rear legs side-view	0.05	0.059	0.13	0.14	0.12	0.25	0.16	0.21
Hoof inclination	0.15	0.057	0.13	0.09	0.08	0.27	0.13	-
Fore udder attachment	0.17	0.057	0.22	0.25	0.14	0.31	0.24	0.25
Rear udder height	0.26	0.055	0.28	-	0.19	-	0.16	0.25
Rear udder width	0.27	0.055	0.26	0.25	0.15	0.19	0.19	-
Udder cleft	0.22	0.056	0.20	0.17	0.15	0.20	0.10	0.33
Udder depth	0.22	0.056	0.32	0.37	0.22	0.29	0.25	0.25
Teat placement	0.23	0.055	0.29	0.41	0.20	0.44	0.22	0.36

1: Gengler *et al.*, (1997) – Jerseys; 2: Pedersen, (1996) – Jerseys; 3: Boldman *et al.*, (1992) – Holsteins; 4: Meyer *et al.*, (1987) - Friesian Holsteins; 5: Misztal *et al.*, (1992) – Holsteins; 6: Luo *et al.*, (1997) – Milk goats

The traits with the highest heritability estimates were wither height (0.32), dairy form (0.27), rear udder width (0.27) and rear udder height (0.26). These traits were also highly correlated with milk, butterfat and protein production, as shown later in Table 5. The biggest differences in the heritability estimates between the two different Jersey populations (Gengler *et al*., 1997 and present study) were for rump angle (0.31 *vs*. 0.22) and udder depth (0.32 *vs.* 0.22). With the exception of rear legs side view, the estimates of the other traits in the present study are in agreement with other studies. Heritability estimates for hooves and legs were also the lowest in the American (Gengler *et al*., 1997) and Danish (Pedersen, 1996) Jersey populations.

The genetic and phenotypic correlation estimates together with estimates from other studies are reported in Table 4. Phenotypic correlation estimates are merely supplied for the sake of completeness. The matrix was not tested to establish whether it was positive definite. The aim of this table is only to report the correlation estimates.

Table 4 Genetic (above the diagonal) and phenotypic (below the diagonal) correlation estimates.

TRAIT	Study	WH	ST	DF	RA	TW	RL	FA	FUA	RUH	RUW	UC	UD	TP
WITHER	1	-	0.79	0.61	0.02	0.45	-0.24	0.29	0.21	0.21	0.33	0.19	-0.15	0.01
HEIGHT	2	-	0.69	0.37	0.18	0.67	-0.12	0.39	0.12	0.22	0.33	0.11	0.04	0.05
	3	-	0.71	0.27	0.03	0.68	-0.09	0.28	0.18	0.16	0.19	0.23	0.26	0.21
	4	-	****	0.24	-0.08	0.51	0.11	0.04	0.19	****	0.13	0.12	0.27	0.05
	5	-	0.14	0.22	0.03	0.63	-0.05	****	-0.06	-0.23	****	0.05	0.11	0.06
STRENGTH	1	0.70	-	-0.43	-0.31	0.34	-0.54	0.49	0.50	0.18	0.25	0.04	-0.11	0.12
	2	0.51	-	0.33	0.14	0.96	-0.23	0.38	0.12	0.17	0.47	0.23	-0.21	0.16
	3	0.49	-	-0.06	-0.01	0.76	-0.20	0.46	0.16	0.23	0.41	0.34	-0.01	0.24
	4	****	-	****	****	****	****	****	****	****	****	****	****	****
	5	0.11	-	-0.51	0.25	0.35	-0.20	****	0.15	-0.27	****	0.02	-0.17	0.04
DAIRY	1	0.18	-0.08	-	-0.19	0.69	0.05	-0.05	0.06	0.87	0.91	0.69	-0.25	0.47
FORM	2	0.24	0.21	-	0.09	0.39	0.14	0.13	-0.15	0.60	0.79	0.41	-0.46	0.21
	3	0.12	-0.11	-	0.14	0.13	0.26	-0.18	-0.19	0.16	0.14	-0.12	-0.30	-0.05
	4	0.16	****	-	-0.06	-0.21	0.26	-0.12	0.23	****	0.08	0.03	0.27	0.18
	5	0.10	-0.41	-	-0.02	-0.10	0.09	****	-0.16	0.04	****	0.09	-0.05	0.02
RUMP	1	0.01	-0.07	-0.04	-	-0.44	0.64	-0.18	-0.27	-0.12	-0.18	0.12	-0.23	-0.08
ANGLE	2	0.12	0.09	0.09	-	0.08	0.06	-0.01	-0.17	-0.03	0.02	0.02	-0.13	-0.01
	3	0.07	0.00	-0.06	-	-0.20	-0.26	-0.05	-0.09	-0.15	-0.11	-0.08	-0.05	-0.10
	4	0.03	****	0.02	-	-0.45	0.23	-0.28	-0.35	****	-0.38	-0.04	-0.37	-0.09
	5	0.05	0.21	-0.05	-	0.11	-0.04	****	-0.02	-0.26	****	0.01	0.06	0.04
THURL	1	0.10	0.06	0.14	-0.08	-	-0.26	0.19	0.57	0.74	0.77	0.40	0.17	0.36
WIDTH	2	0.44	0.70	0.26	0.06	-	-0.21	0.38	0.18	0.27	0.56	0.25	-0.16	0.16
	3	0.28	0.36	0.00	-0.03	-	-0.09	0.32	0.22	0.30	0.41	0.18	0.05	0.15
	4	0.28	****	-0.23	-0.15	-	0.08	0.04	0.15	****	0.18	0.25	0.22	0.02
	5	0.34	0.23	-0.15	0.01	-	0.01	****	0.09	-0.27	****	0.09	-0.03	0.05
REAR	1	-0.03	-0.05	0.01	0.08	-0.20	-	-0.96	-0.50	-0.23	-0.29	0.01	-0.60	-0.25
LEGS	2	-0.06	-0.12	0.04	0.04	-0.10	-	-0.39	-0.23	-0.10	-0.06	-0.04	-0.21	0.04
SIDE	3	-0.03	-0.08	0.12	0.04	-0.02	-	-0.40	0.02	0.00	-0.09	-0.20	0.04	-0.15
VIEW	4	-0.01	****	0.05	0.11	-0.06	-	-0.62	-0.19	****	-0.07	0.14	-0.12	0.19
	5	-0.04	-0.14	0.06	-0.10	0.00	-	****	-0.11	0.03	****	-0.02	0.09	-0.06
HOOF	1	0.06	0.08	-0.01	-0.03	0.03	-0.22	-	0.48	0.08	-0.03	0.21	0.55	0.21
INCLI-	2	0.16	0.18	0.08	0.00	0.19	-0.25	-	0.23	0.21	0.24	0.20	0.16	0.12
NATION	3	0.12	0.15	0.02	-0.06	0.14	-0.12	-	0.06	0.05	0.13	-0.09	-0.11	-0.01
	4	0.05	****	-0.04	-0.07	0.07	-0.27	-	0.32	****	0.18	-0.19	0.09	0.21
	5	****	****	****	****	****	****	-	****	****	****	****	****	****
FORE	1	0.04	0.10	0.01	-0.05	0.09	-0.04	0.07	-	0.87	0.87	0.73	0.84	0.75
UDDER	2	0.08	0.13	0.00	-0.11	0.15	-0.08	0.12	-	0.48	0.26	0.09	0.75	0.36
ATTACH-	3	0.12	0.13	0.11	-0.11	0.11	-0.05	0.16	-	0.47	0.39	0.51	0.78	0.67
MENT	4	0.04	****	0.01	-0.14	0.07	-0.11	0.11	-	****	0.56	0.18	0.75	0.47
	5	-0.04	0.14	-0.10	0.08	0.07	-0.02	****	-	0.24	****	-0.05	0.16	0.04
REAR	1	0.73	0.04	0.27	-0.02	0.16	-0.02	0.01	0.29	-	0.99	0.80	0.32	0.56
UDDER	2	0.14	0.14	0.50	0.01	0.20	-0.04	0.11	0.35	-	0.83	0.45	0.19	0.30
HEIGHT	3	0.15	0.15	0.17	-0.10	0.15	-0.08	0.17	0.43	-	0.91	0.48	0.13	0.47
	4	****	****	****	****	****	****	****	****	-	****	****	****	****
	5	-0.13	-0.14	0.07	-0.14	-0.12	-0.01	****	0.22	-	****	0.05	0.26	0.07
REAR	1	0.58	0.05	0.37	-0.04	0.17	-0.03	-0.01	0.28	0.65	-	0.86	-0.13	0.73
UDDER	2	0.22	0.32	0.59	0.04	0.38	-0.05	0.14	0.23	0.70	-	0.48	-0.17	0.35
WIDTH	3	0.18	0.20	0.17	-0.06	0.23	-0.06	0.18	0.39	0.69	-	0.41	-0.03	0.43
	4	0.08	****	0.03	-0.13	0.13	-0.12	0.09	0.28	****	-	0.22	0.11	0.43
	5	****	****	****	****	****	****	****	****	****	-	****	****	****
UDDER	1	0.68	0.01	0.17	0.02	0.07	0.01	0.03	0.15	0.24	0.28	-	0.46	0.80
CLEFT	2	0.07	0.11	0.26	0.01	0.13	0.01	0.09	0.16	0.34	0.35	-	-0.09	0.43
	3	0.03	0.00	0.21	-0.07	0.06	0.05	0.12	0.30	0.30	0.29	-	0.42	0.66
	4	0.03	****	0.11	-0.03	0.02	-0.03	0.03	0.09	****	0.21	-	0.12	0.27
	5	0.05	-0.01	0.06	0.00	0.03	-0.02	****	-0.11	-0.03	****	-	-0.26	0.46
UDDER	1	-0.04	-0.02	-0.04	-0.05	0.03	-0.06	0.09	0.23	0.06	-0.02	0.09	-	0.47
DEPTH	2	0.06	-0.07	-0.22	-0.15	-0.04	-0.06	0.07	0.48	0.14	-0.04	0.10	-	0.16
	3	0.11	-0.02	0.04	-0.05	0.01	-0.03	0.11	0.33	0.19	0.13	0.27	-	0.43
	4	0.15	****	0.10	-0.08	0.02	-0.08	0.10	0.44	****	0.12	0.11	-	0.24
	5	0.04	-0.02	-0.14	0.06	-0.01	0.06	****	0.15	0.10	****	-0.34	-	-0.08
TEAT	1	0.09	0.03	0.10	-0.02	0.07	-0.03	0.04	0.17	0.15	0.21	0.26	0.11	-
PLACE-	2	0.05	0.11	0.16	-0.02	0.12	0.01	0.07	0.30	0.25	0.27	0.35	0.22	-
MENT	3	0.04	0.01	0.15	-0.05	0.05	0.05	0.11	0.35	0.24	0.25	0.41	0.25	-
	4	0.01	****	0.07	-0.06	0.01	0.00	0.05	0.31	****	0.20	0.15	0.21	-
	5	0.04	0.05	-0.02	0.04	0.03	-0.03	****	0.03	0.03	****	0.36	-0.03	-

1: Present study; 2: Gengler *et al*., (1997) - Jerseys (USA); 3: Misztal *et al.* (1992) – Holsteins; 4: Meyer *et al*. (1987) - Friesian Holsteins; 5: Luo *et al.* (1997) – Milk goats; **** No correlation estimates reported

The genetic correlation estimates obtained between the type and production traits (kg milk, butterfat and protein), as well as the correlation estimates reported in some other studies, are presented in Table 5

Table 5 Genetic correlation estimates between type and production traits (yield; kg)

TRAIT	STUDY	MILK	BUTTERFAT	PROTEIN
Wither	1	0.33	0.33	0.35
Height	2	0.06	0.13	0.13
	3	-0.09	-0.06	-0.05
	4	0.22	0.16	0.25
Strength	1	-0.14	-0.04	-0.07
	2	0.02	0.13	0.10
	3	****	****	****
	4	****	****	****
Dairy	1	0.84	0.78	0.81
Form	2	0.59	0.68	0.67
	3	0.15	0.25	0.32
	4	0.44	0.42	0.43
Rump	1	0.10	0.09	0.12
Angle	2	0.18	0.01	0.11
	3	0.16	0.15	0.17
	4	-0.11	-0.08	-0.11
Thurl	1	0.37	0.36	0.34
Width	2	0.11	0.12	0.11
	3	-0.35	-0.28	-0.29
	4	-0.01	0.01	0.01
Rear	1	-0.01	0.09	-0.03
Legs	2	0.09	-0.01	0.05
Side View	3	0.05	-0.03	0.11
	4	0.07	0.06	0.07
Hoof	1	-0.14	-0.19	-0.12
Inclination	2	0.10	0.13	0.17
	3	-0.12	-0.10	-0.09
	4	0.02	0.05	0.07
Fore	1	0.20	0.23	0.20
Udder	2	-0.31	-0.12	-0.21
Attachment	3	-0.37	-0.14	-0.29
	4	-0.29	-0.23	-0.28
Rear	1	0.70	0.65	0.69
Udder	2	0.19	0.28	0.32
Height	3	****	****	****
	4	****	****	****
Rear	1	0.84	0.79	0.83
Udder	2	0.31	0.33	0.40
Width	3	0.11	0.07	0.02
	4	****	****	****
Udder	1	0.35	0.29	0.33
Cleft	2	0.01	0.17	0.15
	3	0.07	0.11	0.16
	4	0.10	0.16	0.15
Udder	1	-0.53	-0.46	-0.54
Depth	2	-0.44	-0.29	-0.38
	3	-0.52	-0.23	-0.39
	4	-0.48	-0.40	-0.44
Teat	1	0.16	0.17	0.15
Placement	2	-0.03	0.01	-0.01
	3	-0.18	-0.03	-0.11
	4	0.38	0.35	0.36

1: Present study; 2: Misztal *et al*. (1992) – Holstein (USA); 3: Meyer *et al*. (1987)-Holstein; 4:Brotherstone (1994)-Holstein

The genetic correlation estimates obtained in the present study varied from -0.96 for rear legs side-view and hoof inclination to 0.99 for rear udder height and rear udder width (Table 4). A negative genetic correlation between rear legs side-view and hoof inclination was also reported by three other studies (Meyer *et al*., 1987: -0.62; Misztal *et al*., 1992: -0.40; Gengler *et al*., 1997: -0.39). The high correlation estimate between rear udder height and rear udder width may imply that the same trait (udder size) is being classified, as both traits are measured at the same place, *viz*., where the udder tissue connects with the body at the top of the rear udder. The high genetic correlation estimate (0.79) between wither height and strength may be related to the fact that both are a measure of body size since animals that are higher on their legs are normally wider in the chest and deeper through the heart girth. Gengler *et al*. (1997) and Misztal *et al*. (1992) also reported high correlation estimates between these traits. High genetic correlations were found between dairy form and rear udder height (0.87) and width (0.91).

When the results from the two Jersey populations (U.S.A. and S.A.) are compared, two correlation estimates differ substantially. Gengler *et al*. (1997) reported a genetic correlation estimate of 0.33 between dairy form and strength while the correlation estimate in the current study was -0.43. The differences between these estimates may be explained by the fact that the definition of dairy form differs between the two countries. In South Africa, femininity is also taken into consideration, and excessively strong animals will therefore be penalised. The genetic correlation estimate for udder cleft and udder depth was -0.09 for the U.S.A. study and 0.46 for the South African population. The difference is also due to the difference in the definition of udder cleft between the two countries. In the USA, udder cleft refers to the cleft between the two back teats, while in South Africa the depth of the cleft on the rear udder is also taken into consideration. The genetic correlation estimates between milk, butterfat and protein production and dairy form, rear udder height and rear udder width (Table 5) are very high, which is in agreement with the estimates reported by Gengler *et al*. (1997). Very low estimates were, however, obtained between rear udder height and rear udder width. This differs from correlation estimates reported by Misztal *et al*. (1992), Meyer *et al*. (1987) and Luo *et al*., (1997) which is due to the different definitions used in the different populations and different breeds. A high genetic correlation estimate was found between thurl width and rear udder width. Udder cleft had a high genetic correlation with teat placement. All the cited studies reported a high genetic correlation estimate between these two traits (Meyer *et al*., 1987: 0.27; Misztal *et al*., 1992: 0.66; Gengler *et al*., 1997: 0.43; Luo *et al*., 1997: 0.46). A high correlation estimate between fore udder attachment and udder depth was reported by Gengler *et al*. (1997), Misztal *et al*. (1992) and Meyer *et al*. (1987).

Conclusion

Most of the type traits investigated revealed low to medium heritability estimates, and some selection progress should be possible. Although their additive variation is generally low, this aspect should not pose serious limitations to expected selection intensities and resulting gains at present. The leg and hoof traits (rear leg side view and hoof inclination) could, however, be excluded from the improvement programme, as their variation and heritabilities are so low that very little or no selection progress seems possible.

No serious deleterious correlated responses seem likely. In fact, improvement in most of the type traits (dairy form, rear udder height and width) should enhance production yield (kg of milk, butterfat and protein) or, conversely, selection for production yield (kg of milk, butterfat and protein) should lead to a more acceptable type. It is suggested that future breeding values be estimated for all traits fitting a multi–trait model, but reconsidering traits with low estimated heritabilities and/or variation.

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