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## CONTENTS

### Editorial

**A Comparative study of the performance of the Chitungwiza, Marondera and Crowborough sewage treatment plants in Zimbabwe.**

*M. F. Zaranyika, C. Mahamadi and A. S. Mathuthu*

**Sludge deposition and caustic embrittlement in the pre-mature failure of a waste heat boiler steel plate.**

*D.J. Simbi and O.S. Chinyamakobvu*

**Evaluation of Duckweed (*Lemna minor*) as a feed ingredient in the finisher diets of broiler chickens**

*J. Kusina, C. Mutisi, W. Govere, R. Mhona, K. Murenga,  
J. Ndamba, and P. Taylor*

**Vesicular arbuscular mycorrhizal fungi prevalence and diversity in Zimbabwean soils.**

*F.T. Makonese, S. Mpepereki and P. Mafongoya*

**Preparation of water insoluble crosslinked mucilage from *ruredzo* (*Dicerocaryum zanguebarium*)**

*I. Nyambayo and M.A.N. Benhura*

**Intra-herd production level variances for milk yield of Zimbabwean Holstein cows**

*F.N. Mhlanga, S.M. Makuza and V. Rusike*

### Inaugural Lecture

*Meteorite Impacts on Earth and on the Earth Sciences*

### Instructions to Authors



## CONTENTS

A Comparative study of the performance of the Chitungwiza, Marondera and Crowborough sewage treatment plants in Zimbabwe. ....	M. F. Zaranyika, C. Mahamadi and A. S. Mathuthu ..... 1
Sludge deposition and caustic embrittlement in the pre-mature failure of a waste heat boiler steel plate. ....	D.J. Simbi and O.S. Chinyamakobvu ..... 9
Evaluation of Duckweed ( <i>Lemna minor</i> ) as a feed ingredient in the finisher diets of broiler chickens ...	J. Kusina, C. Mutisi, W. Govere, R. Mhona, K. Murenga, J. Ndamba, and P. Taylor ..... 25
Vesicular arbuscular mycorrhizal fungi prevalence and diversity in Zimbabwean soils. ....	F.T. Makonese, S. Mpepereki and P. Mafongoya ..... 35
Preparation of water insoluble crosslinked mucilage from <i>ruredzo</i> ( <i>Dicerocaryum zanguebarium</i> ). ....	I. Nyambayo and M.A.N. Benhura ..... 47
Intra-herd production level variances for milk yield of Zimbabwean Holstein cows .....	F.N. Mhlanga, S.M. Makuza and V. Rusike ..... 55
Inaugural Lecture .....	T.G. Blenkinsop ..... 63
Instructions to Authors .....	..... 81

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# Intra-herd production level variances for milk yield of Zimbabwean Holstein cows

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As evidence has shown that dairy cattle from more variable herds may be over-evaluated, the effect of heterogeneous variances across herd production levels on genetic evaluation was investigated using lactation milk production records of Zimbabwean Holstein cows. A total of 12 420 first lactation milk production records of Zimbabwean Holstein cows were split into three groups (Low, Medium and High) according to herd production level. Preliminary analysis to determine the fixed effects of herd average group, herd, class of cow, year of calving, month of calving and age at calving on milk yield was done. An animal model containing additive genetic effects pertaining to cows, dams and sires was implemented in AI-REML package to estimate additive genetic, residual and phenotypic variances and heritability estimates. The F-max test was used to test for homogeneity of variances. All fixed effects significantly affected milk yield ( $P < 0.05$ ). Estimates of phenotypic, genetic and environmental variances increased with herd production level. Additive genetic variances were 200 275kg<sup>2</sup>, 320 400kg<sup>2</sup>, 376 900kg<sup>2</sup> for Low, Medium and High herd production levels, respectively. Heritability ( $h^2$ ) also increased with herd production level. Estimates of heritability were 0.25, 0.29, 0.30 for Low, Medium and High herd production levels, respectively. Breeding values for the top ten sires varied with herd production levels suggesting a re-ranking of sires due to herd production level. This study showed that intra-herd variances are heterogeneous. Methods for data transformation to account for heterogeneous variances should be developed.

**Keywords:** heterogeneous variances, lactation milk yield, heritability, genetic evaluation

## Introduction

Procedures used to evaluate cows and bulls for production and type traits assume that genetic and environmental variances are independent of the mean and are homogeneous across herds. It is well recognized that variance of milk yield increases with increasing production as does heritability (Sorensen and Kennedy, 1984; Brotherstone and Hill, 1986; Boldman and Freeman, 1988). The problem of heterogeneous variances in genetic evaluation of dairy cattle is that above average animals in the more variable herds may be over-evaluated. Hence, when choosing

animals as future breeding stock across herds, a greater proportion of animals would be selected from the more variable herds. Their estimated breeding values could be greatly affected by within herd variances (Wiggans and Van Raden, 1991).

A practical approach to account for heterogeneity of variance would be to assume that heritability is constant from herd to herd and that the genetic correlation between genetic values in different herd variance groups is one. However, these assumptions can only be valid when adjustments have been made to equalize intra-herd variances. It is not certain what aspects of management contribute to the heterogeneity, but they are presumably associated with differences in methods of feeding concentrates, in particular whether they are given in relation to yield or in fixed amounts, and to what extent special treatment is given to the better performing animals (Brotherstone and Hill, 1986).

In Zimbabwe, application of BLUP genetic evaluation of dairy cattle was implemented in 1996. However, BLUP evaluations assume that variance components are constant across environments. There is a need to assess if this assumption holds. The objectives of this study were to estimate genetic parameters for different herd production levels, and to determine the extent of heterogeneity of variances across herd production levels.

## Materials and Methods

### *Data*

Data consisted of The Zimbabwe Dairy Herd Improvement Association (ZDHIA) milk production records of Holstein cows that freshened between 1979 and 1993. Only 305-day lactation yields records were used for analysis. The basis of 305-day yield is a set of test day yields taken at approximately 30-day intervals, totalling between 1 000 kg and 15 000 kg. For each cow, information on its pedigree, age at calving, month of calving, year of calving, its class, herd and area was included in the data set. First lactation was defined as the first available record without a previous dry period and initiated between 18 and 36 months, hence the age at first calving. Herd averages of milk yields were obtained and grouped into three herd production levels. A herd was nested within a herd production level. The low herd production level was defined as herd average yields less than 5 200 kg, medium production level: 5 200 kg to 6 500 kg and the high herd production level: greater than 6 500 kg. Invalid data, such as month of calving greater than 12 were also deleted. After all the editing, 12 420 records in 126 herds from all over Zimbabwe were available for analysis.

### *Statistical analysis*

Basic statistical analysis was performed using the SAS procedure (1994). This analysis was to determine non-genetic factors important for inclusion in the final model of analysis.

### Model

The following mixed model was used for the preliminary univariate analysis of milk yield:

$$Y_{ijklmn} = \mu + HDAVG_i + H_{j(i)} + YR_k + CL_l + MONC_m + b_1(AGE) + b_2(AGE^2)_{ijklm} + e_{ijklm}$$

where

$Y_{ijklmn}$  = First lactation milk yield

$\mu$  = Overall constant

$HDAVG_i$  = Fixed herd average group effect with  $i = 1, 2, 3$

$H_{j(i)}$  = Fixed herd effects nested within  $HDAVG$  with  $j = 1, 2, \dots, 126$

$YR_k$  = Fixed year effects with  $k = 79, 80, \dots, 93$

$CL_l$  = Fixed class of cow effects with  $l = 1, 2, 3$

$MONC_m$  = Fixed month of calving effects with  $m = 1, 2, \dots, 12$

$b_1(AGE)_{ijklm}$  = age at first calving as a covariate with  $b_1$  as the linear regression coefficient.

$b_2(AGE^2)_{ijklm}$  = age at first calving as a covariate with  $b_2$  as the quadratic regression coefficient.

$e_{ijklm}$  = random residual error distributed as  $N(0, I\sigma_e^2)$ .

The class of cow consisted of the grade, appendix and pedigree cow classes. A grade cow is from parents that are not yet registered with the Zimbabwe Herd Book. An appendix cow is an offspring from an unregistered dam and a fully identified sire. A pedigree cow is fully identified in terms of having both parents registered as pure Holsteins.

Variance components are computed using the AI-REML package of Gilmour (1995), performing a maximum of 100 iterations per herd average group. The  $F_{\max}$  procedure was used to test for homogeneous variances. The following animal model was used for analysis within each herd production level.

$$Y_{ijklm} = \mu + H_i + YR_j + CL_k + MONC_l + b_1(AGE)_{ijkl} + b_2(AGE^2)_{ijkl} + a_m + e_{ijklm}$$

where

$a_m$  = random additive genetic effects pertaining to cows, sires and dams with  $a$  distributed as  $N(0, A\sigma_A^2)$  where  $A$  is the numerator relationship matrix and  $\sigma_A^2$  is the additive genetic variance.

All the other factors were as defined in the previous model. The number of sires differed with herd production level. There were 255 sires in the low herd production level, 620 in the medium and 240 sires in the high herd production level. Each sire was allowed to have at least three daughters in order to ensure a full relationship matrix.

## Results

**Table 1: Number of records (N), mean and standard deviation (SD) of milk yield by herd production level.**

Head Production Level	Milk yield (kg)	N	Mean (kg)	SD(kg)
Low	<5 200	3 285	4 476.38	1 128.51
Medium	5 200-6 500	6 079	5 678.52	1 281.32
High	>6 500	3 056	6 875.65	1 331.53

Table 1 shows the basic statistics for milk yield for each production level. The milk yield ranges for each herd level of production are given. For the grouping criterion, low production level accounted for 26.4 percent of the total records, medium production level 50 percent and the high production level 24.6 percent. By examination of the data, the standard deviation tended to increase with herd production level before model implementation and statistical tests of the estimated variances.

Table 2 shows the sums of squares and p-values for the factors that were adjusted for before computations of variances within herd production levels. All fixed effects (class of cow, month of calving, age at calving, year of calving, herd, age and herd average group) significantly affected milk yield ( $p < 0.001$ ). Milk yield varied significantly with both the linear and quadratic effects of age at calving. The actual milk yield for different ages were not computed since this was not the focus of the study. The purpose of this analysis was to identify factors that would be included in the model for predicting variances.

**Table 2: Sources of variation in milk yield.**

Source of Variation	DF	Sum of Squares	F Value	P Value
Herd production	2	411 070 074.4	177.86	0.001
Herd (Herd Production)	123	2 151 177 578.9	15.13	0.001
Year	14	1 957 951 618.6	21.02	0.001
Class	2	116 746 643.3	50.51	0.001
MONC	11	73 280 891.0	5.76	0.001
Age	1	50 109 349.8	43.36	0.001
Age <sup>2</sup>	1	34 474 883.7	29.83	0.001

**Table 3: Least square means (LS MEAN) for milk yield in different herd production levels.**

Herd Production Level	Milk Yield LS MEAN (kg)	SE
Low	4 187.87 <sup>a</sup>	72.06
Medium	5 517.57 <sup>b</sup>	68.40
High	6 781.59 <sup>c</sup>	163.09

Means with different superscripts are significantly different ( $P < 0.05$ )

Of importance in this study was the effect of herd production level on milk yield. Table 3 presents the Least Square (LS) means for the different herd production levels. The LS means confirmed that the herd production levels used in the study were indeed significantly different in mean milk production ( $P < 0.001$ ).

**Table 4: Estimates of variance components and heritability for milk yield at three different herd production levels.**

Herd Production Level	Phenotypic Variance ( $\sigma_p^2$ )	Additive Variance ( $\sigma_a^2$ )	Residual Variance ( $\sigma_e^2$ )	Heritability ( $h^2$ )
Low	801 100 <sup>a</sup>	200 275 <sup>a</sup>	600 825 <sup>a</sup>	0.25±0.003
Medium	1108 300 <sup>b</sup>	320 400 <sup>b</sup>	787 900 <sup>b</sup>	0.29±0.002
High	1 256 400 <sup>c</sup>	376 900 <sup>c</sup>	879 500 <sup>c</sup>	0.30±0.004

Table 4 shows the phenotypic, additive, genetic and residual variances and heritability within each herd production level. The  $F_{\max}$  test revealed that all the variances were different ( $P < 0.005$ ). Estimates of additive genetic, phenotypic and residual variances increased with herd production level. Heritability of milk yield also increased with herd production level. The results in Table 4 clearly show that homogeneity of variances across herd production levels does not exist. Since this is the case, it is important to examine the breeding values of sires with daughters in all three herd production levels.

Table 5 shows the breeding values of ten sires common in the three herd production levels. It can be noted that the same sire had a different genetic value in each herd production level. Breeding values for a sire increased with herd production level suggesting re-ranking of sires with herd production level. For example, sire 708024 had milk yield breeding values of 457 kg; 590 kg and 600 kg in low, medium and high herd production levels, respectively.

**Table 5: Breeding values of sires in different herd production levels.**

Sire Number	Herd Production Level	Breeding Value (kg)
712011	L	288
712011	M	297
712011	H	299
704021	L	296
704021	M	310
704021	H	398
720016	L	303
720016	M	314
720016	H	372
723032	L	306
723032	M	388
723032	H	416
723004	L	400
723004	M	469
723004	H	512
708024	L	457
708024	M	590
708024	H	600
723006	L	600
723006	M	766
723006	H	801
702080	L	979
702080	M	1168
702080	H	1234
710001	L	1109
710007	M	1200
710007	H	1235
703022	L	1146
703022	M	1246
703022	H	1377

## Discussion

### *Non-genetic factors*

Results in Tables 1 and 2 indicate that numerous non-genetic factors influence milk yield of cows in the same herd, and also contribute to differences between herd averages, as well as to changes in the herd average from year to year. Causes of



environmental variation studied (age at calving, year of calving, month of calving, class of cow and production level) acting singly have very little effect, but when many factors work in the same direction the result may be considerable. Since the focus of the study was on the variance components and heritability estimates, the non-genetic factors will not be discussed in full. It is worth pointing that, in estimating genetic variances, the non-random non-genetic factors should be accounted for. There is need to emphasise recording of these factors by both farmers and the Zimbabwe Dairy Services Association (ZDSA).

#### *Variance components and Heritability estimates*

This study has shown that the phenotypic, additive and residual variances and their ratio heritability increase with herd production level. With the heritability increasing with production levels, it means the use of common heritability for all production levels could result in the mis-ranking of animals. Superior sires in the high-producing herds will be over-evaluated relative to superior sires in the lower producing herds. This has been observed in this study. The breeding values of sires increased with herd production level. Breeding values are a function of the underlying model, which determines the accuracy of the estimated additive genetic variance. If assumptions of the underlying model are correct, then breeding values of sires should be the same across herd production levels.

The results obtained in this study do not deviate from previous studies, which used different populations (Mokhar, 1979; Dannel, 1981; Boldman and Freeman, 1988; Wiggans and Van Raden, 1991). A method that accounts for heterogeneous variances across herd production levels and also regions has been developed for the USA genetic evaluation models (Wiggans and Van Raden, 1991).

Genetic response is a function of selection intensity, heritability and phenotypic standard deviation. Therefore, with different intra-herd variances, selection response depends on the differences in heritabilities among the groups and their relation to the phenotypic variances (Hill, *et al.*, 1984). Optimal proportions to select from each group differ unless the heritabilities are all the same. With intense selection, more individuals are then chosen from the groups with higher heritability. Therefore, selection on performance, regardless of within group variability is biased.

#### **Conclusion**

This analysis shows that there is substantial heterogeneity of variance in yield among dairy herds in Zimbabwe. Phenotypic, additive and residual variances for milk yield varied with herd production level. Sires with daughters in highly variable herds had higher breeding values than when they were evaluated based on milk yields of daughters in less variable herds. As dairy cattle from more variable herds may be over-evaluated, effects of heterogeneous variance need to be accounted for in genetic evaluation procedures. The bias in genetic evaluations has an impact on selection. Response to selection differs with heritability and phenotypic

standard deviation. Therefore, heterogeneous variances will bias selection of superior animals with detrimental effects on selection response. Further investigations on the causes and consequences of the differences in variance are required. A correction procedure, which would equalize variances in all herds, needs to be applied to the Zimbabwe dairy cattle records before genetic evaluations.

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## REFERENCES

- BOLDMAN, K. G. AND FREEMAN, A. E. 1988 Estimates of genetic and environmental variances of first and later lactations at different production levels. *J. Dairy Sci.* **71** Suppl. **2**: 81.
- BROTHERSTONE, S. AND HILL, W. G. 1986 Heterogeneity of variance amongst herds for milk production. *Animal Prod.* **42**: 297–303.
- DANNEL, B. 1981 Interaction between genotype and environment in sire evaluation for milk production. *J. Agric. Sci.* **97**: 38–45.
- GILMOUR, A. 1995 Average information restricted maximum likelihood software package.
- HILL, W. G., EDWARDS, M. R., AHMED, M. K. A. AND THOMPSON, R. 1984 Heritability of milk yield and composition at different levels and variability of production. *Anim. Prod.* **36**: 59–68.
- MOKHAR, S. A. 1979 Progeny testing in dairy bulls at different management level. *Animal Prod.* **28**: 38–43.
- SAS Users Guide: Statistics version 6. 10th Ed. 1994. SAS Inst. Inc. Cary, WC, USA.
- SORENSEN, D. A. AND KENNEDY, B. W. 1984 Estimation of genetic variances from unselected and selected populations. *J. Anim. Sci.* **59**: 1213.
- WIGGANS, G. R. AND VAN RADEN P. M. 1991 Method and effect of adjustment for heterogeneous variances. *J. Dairy Sci.* **74**: 43–50.



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