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Research Article

Estimates of Heritability and Repeatability for Milk Composition Traits of Ethiopian Dairy Cattle Breeds

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Abstract

This study examines the heritability and repeatability of milk composition traits in Ethiopian Boran cattle and their crosses with Holstein Friesian and Jersey breeds. This investigation was carried out at the Holetta Agricultural Research Center (HARC). The study used breeding data from Ethiopian Boran and crossbred dairy cattle (Holstein Friesian and Jersey) to determine milk composition traits such as protein percentage (PP%), fat percentage (FP%), solid nonfat (SNF%), total solids (TS%), and lactose percentage (LP%). WOMBAT software was used to perform statistical studies, including heritability and repeatability estimates, on an animal model. Fixed factors such as lactation season, parity, lactation stage, and calf genotype were added to the model after their significance effect was determined. Heritability estimates were 0.52 for PP, 0.66 for FP, 0.31 for SNF, 0.65 for TS, and 0.86 for LP, showing that these traits have a high genetic effect. The repeatability values for these traits varied from 0.53 to 0.91, exceeding heritability estimates and confirming the dependability of single performance records for selection. Permanent environmental influences have less impact, with strong genetic contributions indicating quick improvement potential through selective breeding. The results emphasize the significance of protein, fat, and lactose percentages as important traits for Ethiopian dairy cow breeding programs. Their high heritability and repeatability values suggest strong genetic predictability and the possibility of making significant genetic gains through focused selection procedures.

Keywords

Crossbreeding, Ethiopian Boran, Heritability, Milk Composition, Repeatability

1. Introduction

Breeding program operation and evaluation of current program performance are dependent on genetic parameter estimations [1-4]. Selection and culling are important procedures in animal breeding since they boost each animal's productivity [5, 6] define heritability and repeatability as two genetic and phenotypic parameter required for good animal breeding programs.

Heritability allows animal geneticists to evaluate if specific traits can be enhanced through selection (predicting how a trait will react to selection), better management methods, or both [7]. Heritability determined the proportion of phenotypic variation in a trait that can be attributed to genetic influences, which helps breeders estimate the potential for genetic improvement through selection. Traits having a greater heritability react better to genetic selection [8].

Repeatability describes how a production attribute or pa-

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rameter observed remains constant in subsequent measures [5]. In other words, repeatability determines an individual's performance consistency throughout several recordings, which aids in determining the dependability of early records in forecasting future performance [9]. Understanding these factors allows researchers and breeders to create efficient breeding programs, enhance management techniques, and increase milk quality and composition.

There have been few studies on estimating the heritability and repeatability of the milk composition traits in Ethiopian cattle, which may be due to a lack of well-structured pedigree data and farm records. However, some estimation has been published [8]. As a result, this study began to quantify the heritability and repeatability of the milk composition traits in dairy cows in central highland Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The study was carried out in the Holetta Agricultural Research Center, located 29 kilometers west of Addis Abeba at 9°00'N latitude and 38°30'E longitude, at an elevation of 2400 meters above sea level. The center is located in a highland agro-ecological zone with an average annual rainfall of 1144 mm, an average temperature of 15℃ (range from 6℃ to 22℃), and a monthly relative humidity of 60% [10].

2.2. Herd Management

The animals grazed on natural grassland for around 8 hours each day and were housed overnight on natural pasture hay. Lactating cows got 3-4 kg of concentrate each milking, but other animals received concentrates only during dry seasons, when feed supplementation was determined by their condition. Clean water was constantly available. Cows and heifers were raised in identical settings with constant care. Calves were weighed at birth, given four days to suckle colostrum before being kept separately for bucket feeding until weaning at 90 days. They were maintained indoors for six months, fed hay ad libitum, and given one kilogram of concentrate per day, which included wheat bran, wheat middling, noug seedcake, and salt. They were maintained indoors for six months, fed hay ad libitum, and given one kilogram of concentrate per day, which included wheat bran, wheat middling, noug seedcake, and salt. Milking was done manually until 2002, when milking machines were installed, and cows were milked twice a day. Routine health treatments were administered, and major illness outbreaks were treated in accordance with the HARC disease control schedule. This management guaranteed that the herd received constant care while also maintaining production and successfully managing health concerns.

2.3. Source of Data

This study used data from the Holetta Agricultural Research Center's experimental dairy cow herds. The study used breeding data from the center's history sheets for Ethiopian Boran and crossbreds with Holstein Frisian and Jersey.

2.4. Traits Studied

The study examined milk composition factors such fat percentage, milk protein percentage (P%), fat percentage (F%), solid nonfat percentage (SNF%), total solids percentage (TS%), and lactose percentage (L%).

2.5. Statistical Analysis

Heritability and repeatability were evaluated using WOMBAT software [11], which fitted an animal model using univariate analysis. Fixed factors (season of lactation, parity, lactation stage, and calf genotype) were included in the model after verifying for significance (P<0.005) using Tukey-Kramer tests using SAS GLM method [12]. The animal model's representation in matrix notation was as follows:

$$\text{Model 1: } Y = Xb + Z_1 a + Z_2 c + e \qquad (1)$$

Where

Y is a vector of observations on the specific trait of the animal;

b is the vector of fixed effects

a is the vector of direct additive genetic effects

c is the vector of permanent environmental effects

X is the incidence matrix of fixed effects

Z1 is the incidence matrix of direct additive genetic effects

Z2 is the incidence matrix of permanent environmental effects,

e is the vector of residual error

The direct additive genetic effects, permanent environmental effects, and residual effects are assumed to be normally distributed with mean 0 and variance Aσ2a, Idσ2c, and Inσ2e, respectively; where σ2a, σ2c, and σ2e are direct additive genetic variance, permanent environmental variance, and residual variance, respectively; A is the additive numerator relationship matrix; Id and In are identity matrices with order equal to the number of dams and number of records, respectively.

3. Result and Discussion

3.1. Heritability Estimates of Milk Composition Traits

Heritability estimates of milk composition traits of Holetta agricultural research center dairy cattle were presented in Table 1. The study found that the milk composition traits of protein percentage (PP%), fat percentage (FP%), total solid percentage (TS%), solid not fat percentage (SNF%), and lactose percentage (LP%) have direct heritability estimates of 0.52±0.02, 0.66±0.02, 0.65±0.03, and 0.31±0.03, respectively. In the current study, all milk composition traits except solid nonfat content exhibited a high heritability, implying that genetic factors play a significant role in determining the diversity found in those traits within the population. Environmental factors like feed, management, and environment have a far less significant effect than genetic ones, and selection can lead to quick improvement. This finding is in agreement with the published values for protein content of milk of Maiwashe et al. and Sharma et al. [13, 14] for the Jersey breed in South Africa (0.53±0.009) and the United States (0.5), respectively. Research by Aynalem [8] for Ethiopian Boran cattle (0.26±0.05) and Misra and Joshi [15] for Karana Fries (0.28) in India found lower direct heritability estimates for protein percentage than the current study. However, Sharma et al. [14] reported in the USA that the present additive genetic heritability was lower than his 0.7% findings for PP.

The direct genetic heritability of fat percentage in milk was lower than that reported by Sharma et al. [17] in the USA for the Holstein breed. However, this finding outperformed tropical breeds reported by Lobo et al. [17] and Maiwashe et al. [13], with values of 0.24 and 0.39±0.009, respectively. The significant amount of variability in heritability estimates for FP might be attributed to differences in the population structure of the herds that contributed the data, the model fitted for the study, the estimation technique, the breed, and the environment in which the data was collected [16].

The current study found a high heritability estimate for total fat% (0.65±0.03), exceeding that of the Karana Fries cattle breed (0.13) in India [15], the Jersey breed (0.59) in the United States [14], and the Boran breed (0.45±0.04) in Ethiopia [8]. This finding was lower than that reported by Sharma et al. [14] for the Holstein dairy cow breed (0.9) in the United States. The direct additive heritability of solid nonfat (0.21±0.09) was moderate, equivalent to the reported value of 0.39±0.04 for Ethiopian cattle breed [8], lower than reported value of 0.68 for Tropical cattle breed [17], and higher than the published value of 0.17 by Misra and Joshi [15]. Sneddona et al. [18] found a moderate direct heritability estimate for lactose content in New Zealand, in contrast with the current study's high heritability of 0.86±0.02.

Permanent additive environmental heritability was 0.02±00, 0.21±004, 0.09±0.03, 0.21±0.09, and 0.05±0.001 for the traits of protein percentage (PP%), fat percentage (FP%), total solid percentage (TS%), solid not fat percentage (SNF%), and lactose percentage (LP%). The heritability of permanent environmental effects was minimal, with the exception of total solid percentage (TS%), which was slightly moderate. Dairy cattle's milk composition traits have low permanent environmental heritability (<0.2), indicating that permanent environmental factors play a minor role in trait variation compared to genetic or temporary environmental factors.

3.2. Repeatability Estimates of Milk Composition Traits

The current investigation found that the milk composition traits protein, fat, TS, SNF, and lactose percentage had a good repeatability estimate, as shown in Table 1. This high repeatability value exceeds the heritability value because repeatability estimates incorporate both permanent environmental variance and additive genetic variance [19]. When repeatability is strong, a single record of an animal's performance is a good predictor of the animal's capacity to produce. Protein, fat, TS, SNF, and lactose percentages were calculated to be 0.54, 0.87, 0.74, 0.53, and 0.91, respectively.

The protein percentage repeatability estimate was lower than reported value of 0.99 for the HF x Boran crossbred in Ethiopia [8], but greater than research report in the United States for the Holstein breed (0.61) [20] and in India for the Karana Fries cattle breeds (0.4) [15]. Lower trait repeatability estimates might also be owing to a greater influence of particular environmental influences on a given record, which may increase variability within animal recordings [21].

According to the research results of Moya [20], Sharma et al. [14], Misra and Joshi [15], and Aynalem [8], the repeatability estimate for fat content was 0.67, 0.68, 0.39, and 0.66, respectively, which was lower than the study result. The total solid percentage of milk had a repeatability report of 0.74, which was lower than Aynlem [8] for Boran in Ethiopia but higher than Sharma et al. [14] and Misra and Joshi [15], who reported values of 0.65 in the United States and 0.49 in India, respectively. The current investigation of the reputability of solid fat content was greater than the published values of 0.65, 0.6, 0.23, and 0.93 for Holstein, Jersey, Karana Fries and Boran in USA, Indian, and Boran, respectively [8, 14, 15].

Table 1. *Estimates of variance components Heritability and Repeatability for Milk composition Traits of Ethiopian Boran and their cross with Holstein Frisian and jersey breed.*

Traits	σ^2_a	σ^2_c	σ^2_e	σ^2_p	h^2_a±se	$h^2_c(c^2)$ ±se	e^2±se	R
P%	0.33	0.01	0.29	0.63	0.52±0.02	0.02±00	0.46±0.02	0.54
F%	0.93	0.29	0.19	1.41	0.66±0.02	0.21±004	0.13±0.02	0.87

Traits	σ^2_a	σ^2_c	σ^2_e	σ^2_p	h^2_a±se	$h^2_c(c^2)$ ±se	e^2±se	R
TS%	3.01	0.41	1.22	4.63	0.65±0.03	0.09±0.03	2.63±0.01	0.74
SNF%	0.69	0.47	1.05	2.21	0.31±0.03	0.21±0.09	0.48±0.01	0.53
L%	0.16	0.01	0.02	0.17	0.86±0.02	0.05±0.001	0.09±0.01	0.91

P%= Protein percentage, F%= Fat percentage, TS%= Total solid percentage, SNF%= Solid not fat percentage, L%= Lactose percentage, h^2_{a}= direct additive effect heritability, $h^2_c(c^2)$= permanent environmental effect heritability, e^2 = Residual effect heritability, σ^2_p= phenotypic variance, σ^2a= direct additive genetic variance, σ^2c= permanent environmental variance, σ^2e= residual variance, Se = standard error, h^2=heritability, R= Repeatability

4. Conclusion

Heritability examines the genetic effect on phenotypic variance, assisting breeders in selecting qualities with strong genetic potential for improvement, whereas repeatability assesses trait consistency over time, assuring accuracy in performance predictions. Protein (0.52), fat (0.66), and lactose (0.86) all have high heritability values, indicating strong genetic influence, making them attractive selection targets. Repeatability values that are above heritability, such as fat (0.87) and lactose (0.91), demonstrate their suitability for early selection. The study underlines the minimal significance of permanent environmental factors and the potential for fast genetic improvements for Ethiopian dairy cattle using successful breeding approaches. Based on the findings, protein, fat, and lactose percentages should be prioritized as major selection qualities in Ethiopian dairy cattle breeding programs due to their high heritability and repeatability.

Abbreviations

e^2	Residual Effect Heritability
F%	Fat Percentage
h^2	Heritability
h^2_a	Direct Additive Effect Heritability
h^2_c (c^2)	Permanent Environmental Effect Heritability
L%	Lactose Percentage
P%	Protein Percentage
R	Repeatability
Se	Standard Error
SNF%	Solid Not Fat Percentage
TS%	Total Solid Percentage
σ^2a	Direct Additive Genetic Variance
σ^2c	Permanent Environmental Variance
σ^2e	Residual Variance
σ^2_p	Phenotypic Variance

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Author Contributions

Fikadu Wodajo Tirfie is the sole author. The author read and approved the final manuscript.

Data Availability Statement

The data supporting the findings of the current study are available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Fields

Fikadu Wodajo Tirfie: Livestock breeding, Quantitative genetics, Molecular genetics, Population Genetics, Animal reproductive Biotechnology, Livestock product processing and technology