PATH ANALYSIS OF CONFORMATION TRAITS AND MILK YIELD OF BUNAJI COWS IN SMALLHOLDER'S HERDS IN NIGERIA

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Abstract

The aim of the present study was to determine the relationships between milk yield and conformation traits of Bunaji (White Fulani) cows using path analysis. The sampled populations were 267 cows in their 1st-3rd lactation order, extensively managed in northern Nigeria in the early to late dry season period. Milk yield positively and significantly correlated with heart girth (HG), fore right teat length (FRTL), fore left teat length (FLTL), rear right teat length (RRTL), rear left teat length (RLTL) and udder circumference (UC) (r = 0.538-0.766; $P < 0.01$). However, the phenotypic correlation between milk yield and udder height (UH) was negative (r = -0.420; $P < 0.01$). This trend was reversed when the direct and indirect effects of these morphological traits on milk yield were considered. The path analysis showed that udder circumference, udder height and heart girth had statistically significant direct effects on milk yield (path coefficients = 0.446 and -0.254; $P < 0.01$ for UC and UH and 0.100; $P < 0.05$ for HG, respectively). The effects of the other body parameters on milk yield were indirectly realised via udder circumference as revealed by t-statistic. The optimum linear multiple regression model included udder circumference, udder height and heart girth with a coefficient of determination (R^2) of 0.665 and determination coefficient of error of 0.335. This model could be useful in predicting milk yield of Bunaji cows on-farm and for selection purposes.

Keywords: milk yield; biometric traits; white fulani cows; path analysis

INTRODUCTION

One of the major problems involved in dairy husbandry concerns early prediction of the lactation yield of cows, as the milk yield level largely determines the profitability of production. Faster assessment of milk yield according to Perz et al. (2008) means a smaller generation gap, and thus better breeding progress on an annual scale. The body build of animals is very important for breeding and performance objective (Heins et al., 2008). Previous research works have shown the significant relationships existing between body conformation and milk production traits (Dimov, 2001; Rao et al., 2007). However, some traits that are important for selection in a dairy herd such as udder circumference, udder bottom height, udder depth and teat circumference may exert direct and indirect effects on milk yield (Keskin et al., 2005). In this way, simple correlation coefficients between the response and predictor variables may not be sufficient in explaining the complex relationships. In order to obviate this deficiency, the use of a multivariate technique, path analysis may be more appropriate.

Path analysis (causal modelling) focuses on examining the web of relationships among measured variables. It allows researchers to recognize the imperfect nature of their measures. It was originally developed to deal with variables that are correlated because of "a complex of interacting uncontrollable and often obscure causes" (Wright, 1934). Path analysis model is not a substitute for regression analysis; rather it is a complementary methodology to regression analysis (Jeonghoon, 2002). A set of additional regressions is added to the original analysis to trace out indirect effects. This complexity allows for a display of all the causal relationships. The direct effect is a directional relation between two variables, i.e. independent and dependent ones. The indirect effect is the effect of an independent variable on a dependent variable through one or more intervening or mediating variables.

The Bunaji (White Fulani) cattle are the most numerous of all Nigerian breeds of cattle, being the principal milk producer in Nigeria accounting for over 90% of the total domestic output. However, relationships among their linear type traits and milk yield have not been examined using a classical statistical tool such as path analysis. The present investigation therefore aimed at determining the relationships between some conformation traits and milk yield of Bunaji cows using path analysis. The results so obtained could be useful in the selection of animals for better milk production.

MATERIALS AND METHODS

Location of study and experimental animals

Data were obtained from 267 randomly selected Bunaji (White Fulani) cows. The animals were selected in their breeding tracts in certain smallholder farms in Nasarawa State, north central Nigeria. The State falls within the guinea savannah agro-ecological zone, and is found between latitudes $7^0 52'$N and $8^0 56'$N and longitudes $7^0 25'$E and $9^0 37'$E, respectively. It has two distinct seasons. The wet season lasts from about the beginning of May and ends in October. The dry season is experienced between November and April. Annual rainfall figures range from 1100 to 2000 mm. About ninety percent of the rains fall between May and September, the wettest months being July and August. Temperatures are generally high during the day, particularly in the months of March and April. The mean monthly temperatures in the State range between 20^o and 34^o, with the hottest months being March/April and the coolest months being December/January. Dense Forest are few and far apart, and are found mainly in lowland areas, particularly where population pressure is less on the land. The animals were subjected to the traditional management grazing system.

Traits measured

Milk yield (MY) and seven biometric traits were measured on each lactating animal weekly for six consecutive months (October, 2008-March, 2009) in the early to late dry season period following standard procedure and anatomical reference points (Mohd.Eisa et al., 2006; Canji et al., 2008). Measurements were restricted to apparently healthy animals in their first, second and third lactations, respectively. Information on the lactation stages of the animals was provided by the herdsmen. Each animal was subsequently tagged for identification purpose. The body parts measured were heart girth (HG), fore right teat length (FRTL), fore left teat length (FLTL), rear right teat length (RRTL), rear left teat length (RLTL), udder circumference (UC) and udder height (UH), measured as the distance from the ground to the udder floor at the points directly in front of the fore and rear teats . The milking routine consisted of udder cleaning and manual pre-stimulation. Milking was done by hand twice a day in the morning (0600-0800hr) and in the evening (1600-1800 hr), respectively. Milk yield was determined using a measuring cylinder and was later converted to the nearest kilograms. Heart girth was measured using a tape-rule. The teats were measured using a thread which was read off on a tape-rule; udder circumference was measured using a tape-rule while a graduated measuring stick was used for the udder height measurements.

Statistical analysis

Means, standard deviations (SD) and coefficients of variation (CV) of weekly milk yield and linear type traits were computed. Pairwise correlations among milk yield and morphometric characters were also determined. Standardized partial regression coefficients called path coefficients (beta weights) were calculated. This was to allow direct comparison of values to reflect the relative importance of independent variables to explain variation in the dependent variable. The path coefficient from an explanatory variable (X) to a response variable (Y) as described by Mendes et al. (2005) is shown below:

$$P_{Y.Xi} = b_i \frac{S_{Xi}}{S_Y}$$

where,

$P_{Y.Xi}$ = path coefficient from X_i to Y (i= HG, FRTL, FLTL, RRTL, RLTL, UC, UH)

b_i = partial regression coefficient

S_{Xi} = standard deviation of X_i

S_Y = standard deviation of Y

The significance of each path coefficient in the multiple linear regression model was tested by t-statistic using the following model:

$$t_j = \frac{b_j - \beta_j}{\sqrt{var(b_j)}} \sim t_{\alpha\,(n-p-1)\,;\; j = 1,2,\text{-------------}, P}$$

where,

$var(b_j)$ = the diagonal member of matrix $s^2\,(X'X)^{-1}$

s^2 = mean square of residual obtained from ANOVA

The indirect effects of X_i on Y through X_j were calculated as follows:

$$IE_{YXi} = r_{XiXj} P_{Y.Xj}$$

where,

IE_{YXi} = the direct effect of X_i via X_j on Y

r_{XiXj} = correlation coefficient between ith and jth independent variables

$P_{Y.Xj}$ = path coefficient that indicates the direct effect of jth independent (exogenous) variable on the dependent (endogenous) variable

Coefficient of determination (R^2) was partitioned into its components using path analysis as follows:

$$R^2 = P^2_{Y.X1} + P^2_{Y.X2} + P^2_{Y.X3} + P^2_{Y.X4} + P^2_{Y.X5} + P^2_{Y.X6} + P^2_{Y.X7} + 2r_{X1X2}P_{Y.X1}P_{Y.X2} + 2r_{X1X3}P_{Y.X1}P_{Y.X3} + 2r_{X1X4}P_{Y.X1}P_{Y.X4} + 2r_{X1X5}P_{Y.X1}P_{Y.X5} + 2r_{X1X6}P_{Y.X1}P_{Y.X6} + 2r_{X1X7}P_{Y.X1}P_{Y.X7} + 2r_{X2X3}P_{Y.X2}P_{Y.X3} + 2r_{X2X4}P_{Y.X2}P_{Y.X4} + 2r_{X2X5}P_{Y.X2}$$

$$P_{Y.X5} + 2r_{X2X6}P_{Y.X2}P_{Y.X6} + 2r_{X2X7}P_{Y.X2}P_{Y.X7} + 2r_{X3X4}P_{Y.X3}P_{Y.X4} + 2r_{X3X5}P_{Y.X3}P_{Y.X5} + 2r_{X3X6}P_{Y.X3}P_{Y.X6} + 2r_{X3X7}P_{Y.X3}P_{Y.X7} + 2r_{X4X5}P_{Y.X4}P_{Y.X5} + 2r_{X4X6}P_{Y.X4}P_{Y.X6} + 2r_{X4X7}P_{Y.X4}P_{Y.X7} + 2r_{X5X6}P_{Y.X5}P_{Y.X6} + 2r_{X5X7}P_{Y.X5}P_{Y.X7} + 2r_{X6X7}P_{Y.X6}P_{Y.X7}$$

where,

$P^2_{Y.Xi}$ = direct effects of explanatory variables (HG, FRTL, FLTL, RRTL, RLTL, UC, UH) in contributing to the variation of Y (Milk yield).

$2r_{XiXj}(P_{Y.Xi})(P_{Y.Xj})$ = combined effects of explanatory variables (HG, FRTL, FLTL, RRTL, RLTL, UC, UH) in contributing to the variation of Y (Milk yield).

SPSS (2001) statistical package was employed in the analysis.

RESULTS AND DISCUSSION

Milk yield and morphological traits

The means, standard deviations and coefficients of variation (%) of weekly milk yield and conformation traits of Bunaji cows are presented in Table 1. The milk yield (kg), heart girth, fore right teat length, fore left teat length, rear right teat length, rear left teat length, udder circumference and udder height (cm) averaged 1.92, 170.34, 5.01, 4.73, 4.90, 4.69, 40.81 and 64.42, respectively. The present value recorded for milk yield is comparable to the range (0.81-2.43 kg) reported by Ahamefule and Ibeawuchi (2008) for the same breed of cattle. The variation in milk yield appeared greater than in any of the measurements and may be due to the influence of the environment on this trait. However, variations in the teat lengths and udder circumference seemed similar.

Table 1: Descriptive statistics of weekly milk yield (kg) and conformation traits (cm) of Bunaji cows

Traits	Mean	Standard deviation	Coefficient of variation
MY	1.92	0.37	19.27
HG	171.52	8.93	5.21
FRTL	5.01	0.82	16.37
FLTL	4.73	0.80	16.91
RRTL	4.90	0.79	16.12
RLTL	4.69	0.78	16.63
UC	40.81	6.77	16.59
UH	64.42	7.62	11.83

MY (milk yield), HG (heart girth), FRTL (fore right teat length), FLTL (fore left teat length), RRTL (rear right teat length), RLTL (rear left teat length), UC (udder circumference) and UH (udder height)

Pairwise correlations

Phenotypic correlations between milk yield and type traits are presented in Table 2. Milk yield had positive and significant association with heart girth, fore right teat length, fore left teat length, rear right teat length, rear left teat length and udder circumference (r = 0.538-0.766; $P < 0.01$). However, milk yield negatively correlated with udder height (r = -0.420; $P < 0.01$). The present results are consistent with the findings of Roy and Saha (2004) where heart girth had positive and significant correlation with milk yield of cows. In a related study, Canji et al. (2008) reported significant association between heart girth and longevity of cows of Slovak Simmental breed. There are varying reports on the relationships between udder traits and milk yield of various species and breeds of livestock. The present finding on the positive relationship between teat length and milk yield agrees with the submission of Narian et al. (1986) in goats. Similarly, Strapak et al. (2005) reported that teat development positively correlated with longevity based on higher milk production. In contrast, Wojcik and Czaja (2002) and Weiss et al. (2004) reported low and significant negative correlations between teat length and milk yield of cows. In their paper, Mohd Eisa et al. (2006) found non-significant positive and negative correlations between the two traits in the different breeds of She-Camel investigated. These observed discrepancies could, however, be attributed to

Table 2: Pearson's coefficients of correlation between milk yield and conformation traits of Bunaji cows**

Traits	MY	HG	FRTL	FLTL	RRTL	RLTL	UC	UH
MY	-	0.538	0.721	0.726	0.689	0.709	0.766	-0.420
HG	-	-	0.605	0.575	0.578	0.545	0.564	-0.161
FRTL	-	-	-	0.940	0.899	0.915	0.829	-0.204
FLTL	-	-	-	-	0.902	0.963	0.831	-0.245
RRTL	-	-	-	-	-	0.931	0.786	-0.170
RLTL	-	-	-	-	-	-	0.815	-0.202
UC	-	-	-	-	-	-	-	-0.229

**Significant at $P < 0.01$ for all correlation coefficients

Table 3: Direct and indirect effects of conformation traits on milk yield of Bunaji cows

Traits	Correlation coefficient with milk yield	Direct effect	Indirect effect							
			HG	FRTL	FLTL	RRTL	RLTL	UC	UH	Total
HG	0.538	0.100*	-	0.067	-0.014	0.042	0.051	0.251	0.041	0.438
FRTL	0.721	0.112	0.061	-	-0.023	0.064	0.085	0.370	0.052	0.609
FLTL	0.726	-0.024	0.058	0.104	-	0.065	0.090	0.371	0.062	0.750
RRTL	0.689	0.072	0.058	0.101	-0.022	-	0.088	0.351	0.043	0.619
RLTL	0.709	0.094	0.055	0.102	-0.023	0.067	-	0.363	0.051	0.615
UC	0.766	0.446**	0.056	0.093	-0.020	0.057	0.076	-	0.058	0.320
UH	-0.420	-0.254**	-0.016	-0.023	0.006	-0.012	-0.019	-0.102	-	-0.166

Table 4: Direct and combined effects of the independent variables contributing to the variation of milk yield of Bunaji cows

Traits	Coefficient of determination (R^2)
Direct effects	
$P^2_{Y^*X1}$	0.010
$P^2_{Y^*X2}$	0.013
$P^2_{Y.X3}$	0.001
$P^2_{Y.X4}$	0.005
$P^2_{Y.\,X5}$	0.009
$P^2_{Y.X6}$	0.199
$P^2_{Y.\,X7}$	0.065
Combined effects	
X 1 (HG) and X 2 (FRTL)	0.014
X 1 (HG) and X 3 (FLTL)	-0.003
X 1 (HG) and X 4 (RRTL)	0.008
X 1(HG) and X 5 (RLTL)	0.010
X 1 (HG) and X 6 (UC)	0.050
X 1 (HG) and X 7 (UH)	0.008
X 2 (FRTL) and X 3 (FLTL)	-0.005
X 2 (FRTL) and X 4 (RRTL)	0.014
X 2 (FRTL) and X 5 (RLTL)	0.019
X 2 (FRTL) and X 6 (UC)	0.083
X 2 (FRTL) and X 7(UH)	0.016
X 3 (FLTL) and X 4 (RRTL)	-0.003
X 3 (FLTL) and X 5 (RLTL)	-0.004
X 3 (FLTL) and X 6 (UC)	-0.018
X 3 (FLTL) and X 7 (UH)	-0.003
X 4 (RRTL) and X 5 (RLTL)	0.013
X 4 (RRTL) and X 6 (UC)	0.050
X 4 (RRTL) and X 7 (UH)	0.006
X 5 (RLTL) and X 6 (UC)	0.068
X 5 (RLTL) and X 7 (UH)	0.010
X 6 (UC) and X 7 (UH)	0.052
Sum total	0.687

change in conformation in accordance with breed, age and stage of lactation of the animal.

Result obtained on udder circumference is comparable to that reported by Strapak et al. (2005) in dairy cattle**.** Kukovics et al. (2006) also reported that udder size had strong effect on milk yield of sheep. According to these authors, as the size of the udder increased, the quantity of milk produced increased. The negative correlation recorded for udder height and milk yield is consistent with documented evidence in literature (Keskin et al., 2005; Mohd. Eisa et al., 2006), indicating that the closer the udder to the ground, the higher the milk production.

Path coefficients of explanatory variables

Path coefficients of the explanatory variables are presented in Table 3. Path analysis provides a basis to measure direct and indirect effects of exogenous (predictor) variables on the endogenous (response) variable. Here, the correlation coefficient is partitioned into its components. One component is the path coefficient (or standardized partial regression coefficient) that measures the direct effect of a predictor variable upon its response variable. The other component is the indirect effect (s) of a predictor variable on the response variable through other predictor variables.

Estimated correlation coefficient at phenotypic level between heart girth and milk yield was 0.538. Its direct effect on milk yield (path coefficient = 0.100) though low, was, however, significant. Strong positive correlation was found between fore right teat length (FRTL) and milk yield (0.721). However, the direct effect of FRTL on milk yield was low (0.142) and non-significant. It was realized indirectly via udder circumference. Similar observations were observed for rear right teat length and rear left teat length (path coefficient = 0.104 and 0.048, respectively). The direct effect of fore left teat length was low, negative and non-significant (-0.001); covered considerably by the indirect effect of udder circumference. The phenotypic correlation between udder circumference and milk yield was the strongest (0.766). This was equally manifested in its direct effect on milk yield which was found to be the greatest (0.446). The present finding is in consonance with the report of Keskin et al. (2005) where the direct effect of udder circumference on milk yield of Akkeci goats was highest. This is an indication that udder circumference is an important trait to be considered while selecting cows for breeding purposes. The relationship between udder height and milk yield was negative (-0.420). Its direct effect on milk yield was equally negative (-0.254), but highly significant.

Coefficients of determination and establishment of a preliminary regression equation

The direct and combined effects of linear type traits on the variation of milk yield are presented in Table 4. Udder circumference had the highest direct contribution to the variation in milk yield ($R^2 = 0.199$). The sum of determination coefficients of any independent variable and two independent variables' interaction in the present study was: $\sum d = 0.687$. According to path analysis principle, the sum of determination coefficients plus the determination coefficient of error is 1. In this case, the determination coefficient of error was $1 - \sum d = 0.313$. The preliminary multiple regression equation was:

Y= 0.443 + 0.004HG + 0.050FRTL – 0.011FLTL + 0.034RRTL + 0.044RLTL + 0.024UC – 0.012UH.

Establishment of optimum regression model

The path coefficients of fore right teat length, fore left teat length, rear right teat length and rear left teat length were all statistically non-significant, as revealed by the t-test. Thus, they were expunged from the regression model to obtain a much more simplified equation. This necessitated the recalculation of the path coefficients for heart girth, udder circumference and udder height, which were earlier found to be significant. Estimates obtained for HG, UC and UH were 0.144, 0.626 and -0.254 respectively, and were found to be highly significant ($P < 0.01$). The direct effects of heart girth, udder circumference and udder height in contributing to the variation in milk yield were: $R^2 = 0.021$, 0.392 and 0.065 for HG, UC and UH, respectively. The combined effects gave R^2 value of 0.187. The optimum multiple regression model was:

Y= 0.292 + 0.006HG + 0.034UC – 0.012UH

The sum of determination coefficient was 0.665 while the determination coefficient of error was 0.335. The present findings are consistent with earlier reports on the use of path analysis in modelling in dairy cows (Naskar et al., 2004) and in goats (Keskin et al., 2005).

CONCLUSIONS

Path analysis revealed that udder circumference had the highest significant direct effect on milk yield of Bunaji cows, followed by udder height and heart girth, respectively. Udder circumference also made the highest single contribution to the variation in milk yield. However, the direct effect of fore right teat length, fore left teat length, rear right teat length and rear left teat length were non-significant, as they were considerably realised via udder circumference. The optimum regression model included forecast indices such as udder circumference, udder height and heart girth. This equation could serve as a useful practical tool for livestock farmers and researchers in the field for predicting milk yield and for selection purposes.

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