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Original Research

Path Analysis of Effective Factors Affecting Milk Yield of Crossbred Dairy Cattle by Using Structural Equation Modeling (SEM)

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Abstract

The present study was conducted to evaluate the relationships among the factors that affect milk yield in dairy cattle and was aimed to determine the direct and indirect effects of these factors on milk yield. In this study, the direct and indirect relationships between dairy cattle's lactation order (LO), the age of animal (Age), lactation length (LL), with milk yield (MY) were determined by Structural Equation Modeling (SEM) through software R using LAVAAN package. In this study, 100 milk yield records were collected from Livestock Farm of CVSc. & A.H., CAU, Aizawl, Mizoram, from year 2010 to 2019. The results showed that, the direct effect of lactation order (LO), age of the animal (Age), and lactation length (LL) on milk yield (MY) were found -0.002, -0.18, & +0.68 respectively. The indirect effect of age of the animal on milk yield through lactation order was found -0.00196 whereas through lactation length it was found +0.2108. The indirect effect of lactation order through lactation length was found -0.1564. The results showed that lactation length (LL) of the animal affects significantly (p<0.05) to the milk yield.

Keywords: Lactation Length, Lactation Order, Milk Yield, Path Analysis, Significant

Introduction

Lactation milk yield is a very important characteristic in all dairy cattle. Factors affecting this trait can be divided into genetically and environmental, such as year and season of calving, age at calving and days in milk. So, to succeed in improving the traits/yield it is important to understand the factors that change the environment of the dairy cattle and can be used to take advantage for improving normal lactation milk yield (Topal & Esenboga, 2001; Hussain *et al.,* 2010). Animal breeding methodology in dairy cattle requires an understanding of the responses and relationship between yield determining traits. These traits have close association with explanatory variables such as age, breed and morphological characters (Irshad, 2015). Statistically, correlation coefficient is the most important parameter of the relationships between variables. But just separately correlation coefficient is not a measure of the existence of a cause & effect relationship between variables (Keskin *et al.*, 2005). All the factors affecting milk yield doesn't have a direct impact on yield. Certain factors have indirect impact due to relationship between them. Due to which it is impossible for all relationships between yield and yield elements to be explained by correlation coefficients. In this respect, it is required that the direct & indirect exposure ways must be presented in detail (Isci *et al.,* 2004). Path analysis is a standardized partial regression coefficient measuring the direct influence of one variable upon the other and permits separation of correlation coefficients into components of direct and indirect effects (Saleem *et al.,* 1999; Farhatullah, 2006; Ahsan *et al.,* 2008).

In this study, to determine and classify the factors affecting lactation milk yield in dairy cattle, we applied structure equation modeling for path analysis. A structural-equation model (SEM) is a system of linear equations among several unobservable variables (constructs) and observed variables. It determines accurate relationship among the factors that have effect on economical traits in animal breeding programs by using latent variables for measurement of random error while path analysis assumes that all variables are measured without error. Path analysis assumes that all variables are measured without error and there is no correlation between the error terms but SEM assumes that there is correlation between them. The goal in building a structural equation model is to find a model that fits the data well enough to serve as a useful representation of reality.

Materials and Methods

The data (100 records of lactating animals) were taken from cross-bred cows of Livestock Farm Complex (LFC), College of Veterinary Sciences & Animal Husbandry, Selesih, Aizawl (Mizoram) from period 2010-2019. Structural Equation Model (SEM) & Correlation has been used for the analysis. Structural Equation Model divided into 2 parts: 1. Structural model that deals with the relationship between latent variables only and 2. Measurement model deals with the relationship between measured variables & latent variable. Construction of SEM includes 5 steps:

1. Model Specification: Model Specification is the exercise of formally stating a model. It is the step in which parameters are determined to be fixed or free. Fixed parameters are not estimated from the data and are typically fixed at zero (indicating no relationship between variables).
2. **Model Identification**: concerns whether a unique value for each and every free parameter can be obtained from the observed data. It depends on the model choice and the specification of fixed, constrained and free parameters.
3. Model Estimation: In this step, start values of the free parameters are chosen in order to generate an estimated population covariance matrix, $\sum(\theta)$, from the model. The goal of estimation is to produce a $\sum(\theta)$ that converges upon the observed population covariance matrix, S, with the residual matrix (the difference between $\sum(\theta)$ and S) being minimized
4. Testing Model Fit: A fitting function value of close to '0' is desired for good model fit. However, in general, if the ratio between X2 and degrees of freedom is less than two, the model is a good fit (Ullman, 1996). In general, a model should contain 10 times as many observations as variables (Mitchell, 1993).
5. Model Manipulation: If the covariance/variance matrix estimated by the model does not adequately reproduce the sample covariance/variance matrix, hypotheses can be adjusted and the model retested.

Data Analysis

The data were analysed by Software R -3.6.2 using LAVAAN Package to compute the results. The LAVAAN package provides users, researchers and teachers a free open-source, but commercial-quality package for latent variable modeling. We can use LAVAAN to estimate a large variety of multivariate statistical models, including path analysis, confirmatory factor analysis, structural equation modeling and growth curve models.

R Codes Used for the Analysis of Data

```
mydata<-read.table(file.choose(), header = T, sep = "\t")
mydata
attach(mydata)
str(mydata)
names(mydata)
library(lavaan)
library(semPlot)
model<-'
LL~Age
LO~Age
LL~LO
MY~Age+LL+LO'
#run the model
fit1=sem(model,data=mydata)
summary(fit1,fit.measure=TRUE,rsquare=T)
parameterEstimates(fit1,standardized=TRUE)
semPaths(fit1,whatLabels = "par",layout = "spring")
semPaths(fit1,whatLabels = "par",layout = "tree2")
semPaths(fit1,whatLabels = "par",layout = "circle")
semPaths(fit1,whatLabels = "par",layout = "circle2")
semPaths(fit1,what="paths",whatLabels="par",rotation=2)
semPaths(fit1,what="paths",whatLabels="stand", rotation=2)
```

Results and Discussion

In present study, path coefficients indicate important effects between factors effecting milk yield (Table 2). Two types of effects were found - the direct effect & indirect effect (through other factors). The direct effect of lactation order (LO) or parity, age of the animal (Age), and lactation length (LL) on milk yield (MY) were found -0.002, -0.18, & +0.68 respectively.

Table 1: Path Analysis by Structural Equation Modeling (SEM)

	LHS op RHS	EST	SE	z-value	p-value	std. lv	std. all
1	LL~Age	9.287	15.027	0.618	0.537	9.287	0.308
2	LO~Age	0.981	0.02	49.076	0	0.981	0.98
3	LL~LO	-6.829	15.003	-0.455	0.649	-6.829	-0.227
4	MY~Age	-59.22	122.855	-0.482	0.63	-59.22	-0.176
5	MY~LL	7.562	0.816	9.268	0	7.562	0.678
6	MY~LO	-0.73	122.553	-0.006	0.995	-0.73	-0.002

Relationship between age and 305 d milk yield revealed that the indirect effect of age of the animal on milk yield through lactation order (parity) was found -0.00196 whereas through lactation length it was found +0.2108. There was a weak relationship between lactation order and 305 d milk yield as the direct effect of lactation order on milk yield was -0.002 & indirect effect of lactation order through lactation length was found -0.1564. The direct effect of lactation length was more powerful than other factors. It was found from the results that lactation length (LL) of the animal affects significantly ($p<0.05$) to the milk yield, and other factors (parity and Age of the animal) effect were non-significant ($p>0.05$) (Table 1 & 2).

Table 2: Direct & Indirect Path Coefficients

Effect	Estimated Value
Direct Effect, LO~MY	-0.002
Direct Effect, Age~MY	-0.18
Direct Effect, LL~MY	0.68
Indirect Effect, Age~MY via LO	-0.00196
Indirect Effect, Age~MY via LL	0.2108
Indirect Effect, LO~MY via LL	-0.1564

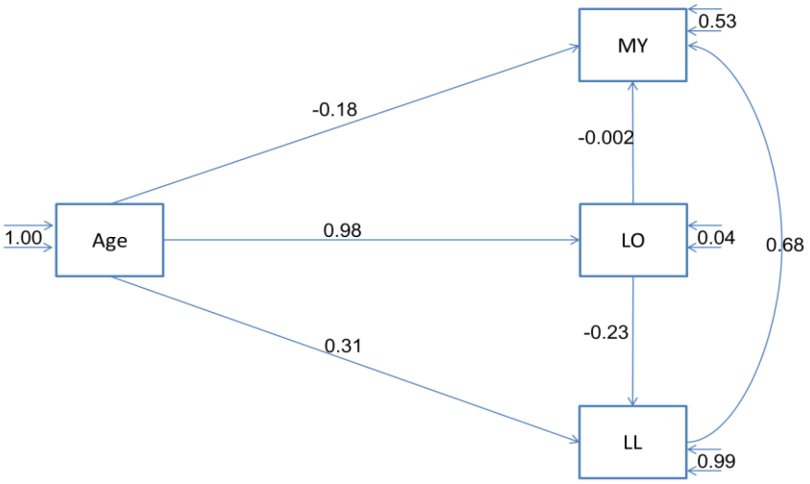

Figure 1: Path Diagram

The result showed positive relationship between lactation length & milk yield and age & lactation order (parity). The negative relationships were found between age & milk yield and lactation order & milk yield. The relationships observed between age & lactation length and age & milk yield were found non-significant (P>0.01). Significant (P≤0.01) relationships were observed between age & lactation order and lactation length & milk yield (Table 3).

Table 3: Correlation among parameters

		Age	LL	LO	MY
Age	Pearson Correlation	1	0.097	0.980**	-0.106
	Sig. (2-tailed)		0.339	0	0.295
	N	100	100	100	100
LL	Pearson Correlation	0.097	1	0.1	0.687**
	Sig. (2-tailed)	0.339		0.321	0
	N	100	100	100	100
LO	Pearson Correlation	0.980**	0.1	1	-0.1
	Sig. (2-tailed)	0	0.321		0.32
	N	100	100	100	100
MY	Pearson Correlation	-0.106	0.687**	-0.1	1
	Sig. (2-tailed)	0.295	0	0.32	
	N	100	100	100	100

***Correlation is significant at the 0.01 level (2-tailed)*

The result reveled that age and lactation order (parity) had negative effects on milk yield. The direct effect of lactation length was positive. In contrast to these results, the effect of lactation order on milk yield was found to be statistically significant by Ozçelik and Arpacik (2000), Şeker *et al*. (2009). Correlations between lactation period and lactation milk yield have been reported as non-significant and negative by Mundan *et al*. (2009). Gorgulu (2011a) found the highest relationship between 305 d milk yield and the age of animal and also, found highly significant positive relationship between the number of lactation and 305 d milk yield. Based on correlations, Gorgulu (2011b) reported that number of lactation & age were the most important factors affecting milk yield components in jersey cattle. Chaudhary *et al.* (2020) reported that the change in milk yield decreases with time. One-year increase in age corresponds to 0.0012 units less in milk yield change rate.

Conclusion

The present study highlights that the direct effect of lactation order (LO), age of the animal (Age), and lactation length (LL) on milk yield (MY) were found -0.002, -0.18 & +0.68 respectively. The results obtained in this study showed that the structural equation modeling for analysis of path coefficient is highly useful, allowing us to know the real contribution of group independent variables on a dependent variable through their direct and indirect effects compared to simple correlations to study the degree of association and interrelationship between the milk yield components in cross-bred cows. At the same time, the path coefficients analyzed by structural equation model showed that the lactation length was the main factor affecting milk yield in cross-bred cows.

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Conflict of Interests

There is no conflict of interest.

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