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Assessment of Dairy Cows for Milk Yield in the Cool Tropical Climate of Plateau State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Authors DOO designed the study. Author ROO performed the statistical analysis. Author OOA wrote the protocol. Author JMM managed the literature searches. Author DSBU managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Genetic improvements of milk yield in the tropics necessitate the use of exotic cattle to the upgrade the performance of local cattle. The data for the study came from two different genotypes namely Holstein Friesian and FriesianxBunaji crossbred on the Plateau State in Nigeria. Milk production traits measured were 305-day fat corrected milk yield, daily milk yield, 100-day fat corrected milk yield, total fat yield, total protein yield and lactation length. Six milk production indices (Fat corrected milk yield kilogram weight; FCM Kg W, fat corrected milk yield kilogram metabolic weight; FCM Kg MW, fat corrected milk yield per day per kilogram weight; FCM/day/kgW, fat corrected milk yield per day per kilogram metabolic weight; FCM/day/kgMW, net energy efficiency and dairy merit). The R

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3.0.3 statistical software was used for basic descriptive, t-test and regression analysis. Milk production traits were significantly (P<0.05) influenced by genotype. Neural network models had the best prediction accuracy for estimating milk yield. It is concluded that considerable genetic variation existed between genotypes in milk production and efficiency traits.

Keywords: Neural network; milk yield; dairy; tropical.

1. INTRODUCTION

Dairy cattle exhibit tremendous phenotypic diversity, including a greater variation in milk yield than any other mammal due to selective pressure to improve milk production [1]. Milk yield is the most important economic trait that determines productivity and profitability in dairy cattle [2]. The introduction of improved exotic breeds (Friesian, Brown Swiss, Jersey and Simmental) by government and private farms is one of the options for upgrading cattle for milk production in Nigeria. Exotic dairy cattle have been imported to Nigeria in large numbers during the last 25 years to enhance and optimize milk production. Milk production will need to nearly double in the world over the next decade to follow population and income growth [3]. The strongest demand for milk and milk products are anticipated for developing countries where population growth is expected [4]. Nigeria spends an estimated amount of $1.3 billion on the importation of dairy products and government's target is to double milk production over the next three to four years in order to meet up with domestic consumption [5]. With a population higher than 180 million people, the country is currently going through low local milk production while importing more than 70 percent of its dairy products [6]. An average, local cow in Nigeria is said to produce 1 kg of milk a day, showing there is a long way to go before reaching self-sufficiency [7]. Unfortunately, the domestic output of about 503,000 metric tonnes of milk [5] from an estimated 14 million cattle can hardly satisfy the dairy demands of an ever increasing population of Nigerians [7]. A comprehensive understanding of milk yield and composition is imminent to bridge the gap in protein insufficiency. The use of novel tools such as genetic algorithm programs for optimization of the estimates of milk yield in Nigeria dairy industry have not been conceived. Therefore, this study is design to assess dairy cows for milk yield in the cool tropical climate of Plateau State, Nigeria.

2. MATERIALS AND METHODS

2.1 Animal Management

The cows were grouped into paddocks ranging in size from 1 to 2.5 hectares according to breed, age and stage of lactation. The cows were kept outdoors in paddocks all year round except during the morning and after-noon milking in herringbone milking parlour when they were fed hay, mainly *'acha', Digitaria exilis,* and maize silage in the dry season (October to April). In the wet season (May to September) the animals were allowed to graze rotationally in paddocks sown with *Hyparrhenia rufa, Digitaria spp, Andropogon guyanus, Stylosanthes gracilis,* Bermuda, Rhodes in correlation with other naturally growing grasses of the area among which are *Eleusine indica* and *Penisetum perpurenm.* Mineral block and water were available to cows on pasture *ad-libitum*. In addition the milking cows received a daily 100 kg concentrate supplement comprising of 70% maize, 15% groundnut cake, 10% cotton seed cake, 4.9% churn mineral and 0.1% vitamin and trace mineral premix. Stubborn cows were culled from milking. Also molasses was added to their ration. This production ration was offered in two equal installments during the morning (07.30 hrs) and afternoon (15.00 hrs) milking. Calves suckled their dams for the first 3 days postpartum after which they were bucket fed milk until weaning at 42 days of age.

2.2 Data Collection

A total of 3063 milk yield records from 2001 through 2015 from Holstein Friesian and FriesianXBunaji crossbred cattle collected from Integrated Dairy Farm, Jos Plateau, State, Nigeria.

2.3 Measures of Milk Yield Indices

Fat corrected milk (FCM) = [(0.4*milk yield (kg) + [(15*fat yield (kg)]

$FCM / kgW = \frac{FCM}{W}$, where w=body weight (kg)

$FCM / kgMW = \frac{FCM}{M^{0.75}}$, where MW=Metabolic bodyweight (kg) and 0.75 is the power function for calculating MW

$$FCM / day / kgW = \frac{FCM / day}{W}$$

$$FCM / day / kgMW = \frac{FCM / day}{W^{0.75}}$$

$$Net\,energy\,efficiency\,(NEE)(\%) = \frac{750 * FCM / day * 100}{(750 * FCM / day) + 70W^{0.75}}$$, where

750=kilocalories of /energy per kg of FCM and 70= Basal metabolic rate

$$Dairy\,Merit\,(DM)(\%) = \frac{NEE * FCM / day}{FCM / day + 0.173W^{0.75}}$$

2.4 Statistical Model and Analysis

2.4.1 Data preparation

Data preparation entailed the entry of data into an excel worksheet and statistical manipulation of the data to compute some of the indices that were not directly measured on the cows. Edits were performed to remove records that were incomplete or had obvious errors.

2.4.2 Statistical model

Model describing the ANOVA was given as; $Y_{ijkl} = \mu + \alpha_i + \delta_k + P_s + Y^c + e_{ikl}$, where Y_{ikl} = observed measure, μ = the overall mean, α_i = i^{th} fixed effect of genotype, δ_k = k^{th} covariate effect of days in milk, P_s=S^{th} of parity effect, Y^c=C^{th} effect of year of calving and e_{ikl} = residual random error.

Preliminary descriptive statistical analyses were done before statistical modelling and analysis to test the significance of fixed effects. All descriptive statistical analyses (Mean, coefficient of variation and standard error of mean) were done using R commander (2016) Software. The Tukey's procedure for mean comparison was used to rank the means after a significant effect (P<0.05) was observed. The ordinary least squares method using PROC REG in Statistical Analysis Software (S.A.S 9.4, 2014) was used to compute the regression analysis.

3. RESULTS AND DISCUSSION

Table 1 shows the least squares means and coefficients of variation of the thirteen milk measures of the two genetic groups. Milk production and efficiency traits were greatly influenced (P<0.01) by the genotypes of cows in Plateau State, with the exception of total solid. There were highly significant (P<0.01) differences between the two genetic groups. The mean fat corrected milk yield (N=3063) for the combined genotypes determined at the 305^{th} day of milk production was 4040.0±74.92 kg, with the highest (4996.8±92.64 kg) recorded by Holstein Friesian cows, while FriesianxBunaji crossbreds had the least milk yield of 3322.8±29.16 kg. The 305dFCM accounted for 37.64 % of the total variation in milk yield. The Holstein breed had an increment of 50.38% for 305dFCM as compared to HolsteinxBunaji respectively. 305 FCM /cow/per day was statistically different (P<0.05) between the two genetic groups. Genetic group effect was significant (P<0.05) on 100dFCM, with each of the two genotypes being highly statistically (P<0.01) different from the other group.

Holstein had significantly higher values for milk yield than HolsteinxBunaji. The 100dFCM from Holstein Friesian was 29.77% heavier than FriesianxBunaji. The effect of genotypes was significant (P<0.05) on 305d fat yield, protein yield and lactation length accounting for 37.83%, 51.30% and 19.52% of the total source of variation. Genetic group effect was highly significant (P<0.01) on milk efficiency traits (FCMKgW, FCMKgMW, FCM/day/kgW, FCM/day/kgMW, net energy efficiency and dairy merit). The mean FCMKgW, FCMKgMW, FCM/day/kgW, FCM/day/kgMW, net energy efficiency and dairy merit for the combined genotypes were 6.9±0.16 kg, 33.3±0.74 kg, 0.02±0.005 kg, 0.1±0.02 kg, 52.6±0.55% and 73.0±0.47%, respectively. The efficiency estimation of milk production in genotypes of cows were highly variable (CV=14.75 - 42.45%). In Plateau State, Holstein Friesian cows significantly had higher performance for milk production and efficiency traits than FriesianxBunaji cows. This implies that animals show more adaptation to the mountainous climate which make them less aware of heat stress, thus initiating milk production at optimal level. The superiority of purebred animals to HolsteinxBunaji for milk production and efficiency traits in this study needs not be deliberated as it is a generally accepted trend in animal genetic improvement work. This observation is in agreement with the works of [8] and [9] in Plateau State, who reported superior performance of Holstein over different levels of HolsteinxBunaji crossbreds. The mean 305FCM yield of 4996.8 kg for Holstein cows obtained in this study is not in coherence with the 2678 kg reported by [10] in Ethiopia, 3678.09 kg by [8] and 4457.72 kg by [9] in Nigeria but still lower than 8600 kg recorded in more favourable conditions for all lactations in Holstein cows [11]. The mean 305dFCM yield per lactation in this study is higher than 9.43 kg reported by [10] in Ethiopia for Holstein cows. Fat and protein yields adjusted to 305 days were lower than most of recent estimates in the USA and Canada [11]. The mean 305dFCM yield per lactation in the developed countries is much higher than in developing countries (average 40 kg/cows/day) [12].

3.1 Final Candidate Model for Milk Prediction over a 305-day Full Cycle in Integrated Dairies Limited in Plateau State

Table 2 shows the model equation, adjusted coefficient of determination, root mean square error and Bayesian information criterion in predicting FCM305d in Plateau State. Neural network model outclassed MLR and GFA in predicting FCM305d yield with lower RMSE and BIC for Plateau State in Holstein Friesian and FriesianxBunaji. The MLR was more accurate than the GFA with over 9% increment of the FCM305d yield prediction. The MLR and NN were more sensitive in Holstein Friesian dairy cows than FriesianxBunaji in modelling FCM305d yield. The FY and TL were the observed traits that predicted FCM305d in all the models accurately for FriesianxBunaji in Plateau State. It was observed that the accuracy of the prediction method was consistently higher in NN than MLR and GFA studied albeit with different precision across the two genotypes of dairy cows in Plateau State.

The observed high adequacy of NN as the best model for predicting fat corrected 305-day milk yield using part period milk production (FCM100), milk components and conformation traits was consistent with the report of several authors [13; 14; 15]. [16] compared qualitative properties of MLR and two different models of NN. The MLR model, depending on the region, was characterised by R^2 values ranging from 78 to 86%. A classical NN showed lower R^2 values while that with polynomial post-processing demonstrated higher values of R^2 (0.80–0.90), which was still lower than the range of 0.98 – 0.99 (NN) reported in this study.

Table 1. Least squares means (±standard error) and coefficient of variation of milk production and efficiency traits among different genetic groups of cows in Integrated Dairies Limited in Plateau State

Traits	Holstein Friesian (n=2042)	Friesian x Bunaji (n=1021)	Overall (n=3063)	CV %	SEM
305 FCM (kg)	4996.8±92.64^a	3322.8±29.16^b	4040.0±74.92	37.64	224.82
305 FCM /cow/per day(kg)	14.0±0.37^a	8.9±0.06^b	11.06±0.51	25.05	1.88
100d FCM (kg)	1585.3±20.34^a	1221.6±13.46^b	1345.7±46.94	50.42	50.47
305d Fat yield (kg)	186.8±7.34^a	110.3±3.44^b	115.3±4.09	51.30	21.91
305d protein yield (kg)	151.6±3.94^a	84.1±1.37^b	116.2±3.04	37.83	14.16
Total solid (g/100g)	12.2±0.07	12.4±0.08	12.3±0.05	6.33	0.39
Lactation length (days)	357.3±5.35^b	372.6±4.72^a	365.3±3.58	19.52	5.52
FCM Kg W	7.7±0.20 ^{a}	4.4±0.10 ^{b}	6.9±0.16	42.45	0.49
FCM Kg MW	37.1±0.89 ^{a}	21.22±0.42^b	33.3±0.74	40.62	2.17
FCM/day/kgW	0.01±0.001^a	0.3±0.001^b	0.02±0.005	41.45	0.002
FCM/day/kgMW	0.1±0.02^a	0.2±0.01^b	0˙1±0.02	40.62	0.01
NEE (%)	55.7±0.66^a	42.27±0.49^b	52.6±0.55	25.96	2.96
Dairy Merit (%)	75.6±0.61^a	63.18±0.31^b	73.0±0.47	14.75	2.56

^{ab}Means of the same trait across genetic groups with different superscripts differ significantly (P<0.05);); d-days; FCM-Fat corrected milk; kg-kilogram; MW-Metabolic weight; W-Weight; NEE –Net energy efficiency; CV-Coefficient of variation; SEM-Standard error of mean

Table 2. Prediction equation for FCM305d from milk components and conformation traits using different models in Integrated Dairies Limited in Plateau State

Genotype and Herd	Models	Equation	Adj R^2	RMSE	BIC
Holstein Friesian	MLR	FCM305=1012.4+3.76ST-0.24FCM100+23.53FY+0.66PY-3.18UC-0.44BWT	0.98	0.06	1020.22
	NN	FCM305=3844.4-0.02ST+0.02BD +0.01FCM100+0.009FY+0.009PY -0.003UC-0.003BWT	0.99	0.01	960.42
	GFA	FCM305=348.7+6.82ST-8.93BD-0.13FCM100+20.3FY+1.28PY-9.39UC-1.18BWT	0.87	0.14	1290.50
FRxBJ	MLR	FCM305d=1512.8+21.1FY-50.9TL	0.96	0.05	1022.36
	NN	FCM305d=868.4 -2.08FY-0.17TL	0.98	0.03	1018.41
	GFA	FCM305d=1515.9-21.1FY-51.4TL	0.96	0.07	985.55

FCM305-Fatcorrectedmilk for 305day; FRXBJ-FriesianxBunaji; JXBJ-JerseyXBunaji; NN-Artificial neural network; MLR-Multiple linear regression and GFA-Genetic algorithm function approximation; BWT-Bodyweight; ST-stature; UC-Udder clearance; FCM100-Fat corrected milk at 100 day; BD-Bodydepth; FY-Fat yield; PY-Protein yield; Adj R^2-Adjusted coefficient of determination; Bayesian information criterion; d=day, RMSE-Root mean square error.

4. CONCLUSIONS

Holstein Friesian cows had strong dairy strength for milk volume and components in the cool tropical climate of Plateau State. It is also recommended that Neural Network models will be appropriate in describing the milk production pattern and prediction of 305 day fat corrected milk yield under different climatic gradients in Nigeria. Genetic function algorithm promises to be a veritable and added tool for milk yield prediction under a large scale evaluation.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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