Genetic and Phenotypic Parameters of Birth Weight Traits in Fulbe Sheep in Cameroon

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Key words

Fulbe sheep - Birth weight - Heritability - Genetic parameter - Genetic correlation - Cameroon.

Summary

Data on the birth weight of 610 lambs produced from 21 rams randomly mated with 199 primiparous Fulbe ewes were collected between 1993 and 1996 at the Institute of Agricultural Research for Development, Garoua Research Station. Data were used to identify and quantify factors affecting the birth weight (BWT) and litter birth weight (LBWT), and to estimate direct and maternal heritabilities, genetic and phenotypic correlations between direct and maternal effects. Results indicated that 26.86% variability in BWT and 34.20% in LBWT were caused by sex, season of birth, year of birth, parity, birth type and feed group. Heavier lambs (2.36 kg) were produced during the cold dry season (October to January). Mixed litters had significantly higher weights (3.97 kg) than litters only composed of either males (2.73 kg) or females (2.64 kg). Estimates for direct and maternal heritabilities were 0.61 and 0.32 for BWT, and 0.30 and 0.27 for LBWT. Estimates for genetic and phenotypic correlations between direct and maternal effects were -0.48 and 0.28 for BWT, and -0.65 and 0.57 for LBWT. Due to the high negative estimates for genetic correlations, long-term selection on own performance for either BWT or LBWT will adversely affect maternal performance.

■ INTRODUCTION

The potential of sheep production in Cameroon is high as they are found in all ecological zones of the country. The estimated population is about 2,358,100, and about 57.8% is produced in the Far North and North provinces (Njwe, pers. commun.). Production in these two provinces plays an essential role in the economy and survival of the rural people. It provides them with food or immediate cash when need arises.

The sheep are characterized by a relatively small size, high reproduction efficiency, heat tolerance and resistance to some diseases. These characteristics help them to be flexibly integrated into small economic units, with little capital investment and financial risks. Major problems, however, include poor nutrition, high disease rates and parasitic infestations, slow growth rates and high lamb mortality (3, 6, 11).

The present study therefore aimed at setting up some strategies to increase reproductive performance through the identification and quantification of environmental factors that affect birth weight traits. It also aimed at estimating genetic and phenotypic parameters that could be useful for future selection decisions.

■ MATERIALS AND METHODS

Data on birth weight (BWT) and litter birth weight (LBWT) were collected from a Fulbe sheep flock kept between 1993 and 1996 at the Garoua Station of the Institute of Agricultural Research for Development. Description of the experimental site and prevailing seasons have been documented (5, 11).

Flock management

The flock initially composed of 240 weaner ewes was divided into four groups of 60 each, with one ram found within a group at a given time. The rams were rotated between the groups. All four groups grazed rotationally on unimproved pastures. Animals in group one (S) were supplemented with 200 g cottonseed cake. Those in group two (ST) were supplemented with 200 g cottonseed cake, vaccinated against *peste des petits ruminants* (PPR) and treated against internal and external parasites. Animals in group three (T) were only vaccinated against PPR and treated for internal and external parasites. Those in group four (NST) were

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neither supplemented, nor vaccinated against PPR, nor treated for internal and external parasites.

Data collection

Final data were collected from mating 21 rams with 199 ewes (Table I). At birth each lamb was identified with an ear tag and pedigreed with ram and ewe. The lambs were weighed within 24 h. Information on lamb sex, birth type, parity, season and year of birth and feed group were recorded.

Analytical technique

The data were analyzed with SAS (13) using the general linear model procedure to obtain least squares means (LSM) and standard errors (SE) for BWT and LBWT (combined weights of lambs per ewe for each parturition in kilograms). Triplets were excluded from the analysis because they were few in numbers. Restricted maximum likelihood estimates were obtained with the MTDFREML software (2). An animal model was used for each of the traits with the direct, maternal effect correlated to the direct, permanent maternal environment uncorrelated to the direct and maternal effects and environmental effect associated to the direct effect, fitted as random effects.

Two linear models were used to estimate least squares means and standard errors.

Model 1: Estimation of least squares means and standard errors for birth weights

$B_{ijklmnop} = \mu + RF_{ik} + F_k + G_l + T_m + P_n + S_o + e_{ijklmnop}$, where

$B_{ijklmnop}$ is the birth weight of the p^{th} lamb

μ is the overall mean

RF_{ik} is the random effect of the i^{th} ram within the k^{th} feed group

F_k is the fixed effect of the k^{th} feed group with k = 1, 2, 3 and 4

G_l is the fixed effect of the l^{th} sex with l = 1, 2

T_m is the fixed effect of the m^{th} birth type with m = 1, 2

P_n is the fixed effect of the n^{th} parity with n = 1, 2... 5

S_o is the fixed effect of the o^{th} season of birth with o = 1, 2, 3, and

$e_{ijklmnop}$ is the random error attributed to the p^{th} lamb.

Model 2: Estimation of least squares means and standard errors for litter birth weight

$B'_{ijklmnopq} = \mu + RF_{ik} + F_k + G_l + T_m + P_n + S_o + e_{ijklmnop}$, where

$B'_{ijklmnop}$ are the combined weights of lambs per ewe per parturition

μ is the overall mean

RF_{ik} is the random effect of the i^{th} ram within the k^{th} feed group

F_k is the fixed effect of the k^{th} feed group with k = 1, 2, 3 and 4

K_l is the fixed effect of the l^{th} sex with l = 1, 2, 3

T_m is the fixed effect of the m^{th} birth type with m = 1, 2

P_n is the fixed effect of the n^{th} parity with n = 1, 2... 5

S_o is the fixed effect of the o^{th} season of birth with o = 1, 2, 3, and

$e_{ijklmno}$ is the random error.

Estimation of genetic and phenotypic parameters

The estimates for observable (co)variance components were obtained from an animal model presented in a matrix notation as follows:

$\underline{y} = X\underline{b} + Z_1\underline{a} + Z_2\underline{m} + Z_3\underline{c} + \underline{e}$, where

$\underline{y}$ is the observation vector for the birth weight or litter birth weight of lambs

X is an incidence matrix relating observations to fixed effects

$\underline{b}$ is a vector of fixed effects (sex, parity, season, year of birth, birth type and feed group)

Z_1, Z_2 and Z_3 are incidence matrices relating direct, maternal and maternal permanent environment effects to $\underline{y}$

$\underline{a}$ and $\underline{m}$ are correlated random vectors for direct and maternal effects

$\underline{c}$ is an uncorrelated random vector for the maternal permanent environmental effect, and

$\underline{e}$ is a random vector associated with error.

Direct (h^2_a) and maternal (h^2_m) heritabilities, genetic (r_{am}) and phenotypic (r_p) correlations between direct and maternal genetic effects were obtained from observable (co)variance components as follows:

$h^2_a = \sigma^2_a/\sigma^2_p$

$h^2_m = \sigma^2_m/\sigma^2_p$

$r_{am} = \sigma_{am}/\sigma^2_p$

$r_p = \sigma^2_e/\sigma^2_p$ where

σ^2_a is the direct additive genetic variance component

σ^2_m is the maternal additive genetic variance component

σ^2_e is the environmental variance

σ^2p is the total phenotypic variance component

r_{am} is the genetic correlation between direct and maternal genetic effects, and

σ_{am} is the direct maternal genetic covariance.

Table I

Summary of data structure

FG	Prog.	Rams	Ewes	Prog./sire	Prog./ewe	Dam/sire
S	262	9	80	29.11	3.28	8.89
ST	156	8	48	19.50	3.25	6.00
T	137	6	46	22.83	2.98	7.67
NST	55	6	25	9.17	2.20	4.17

FG: feed group; Prog.: progeny; S: supplementation group; ST: supplementation and treatment group; T: treatment group; NST: no supplementation and no treatment feed group

■ RESULTS

Factors affecting the birth weight

The birth weight of the Fulbe sheep was significantly affected by sex ($P < 0.05$), birth type ($P < 0.001$), parity ($P < 0.01$), season of birth ($P < 0.05$), year of birth ($P < 0.05$) and feed group ($P < 0.05$). These effects accounted for 26.86% of the total variation (Table II). Single lambs were 0.45 kg heavier than twin lambs. There was a consistent increase in BWT from the first to the fourth parity. Heavier lambs averaging 2.36 kg were produced in the cold dry season (season 1), followed by the hot dry season (season 2) with an average of 2.34 kg. Ewes that were vaccinated against *peste des petits ruminants*, treated against internal and external parasites, and supplemented with cottonseed cake produced the heaviest lambs at birth (2.39 kg).

Factors affecting the litter birth weight

Sex of lamb ($P < 0.001$), birth type ($P < 0.001$), parity ($P < 0.05$), season of birth ($P < 0.05$), year of birth ($P < 0.05$) and feed group ($P < 0.01$) also significantly affected LBWT and accounted for about 34.20% of the total variation (Table II). Heavier LBWT (3.97 kg) were produced from mixed litters. The lower BWT for twin births (2.03 kg) was offset by heavier LBWT (3.10 kg). The ewes that were supplemented, vaccinated against PPR and treated against external and internal parasites produced the heaviest litters (3.96 kg) as was the case with BWT.

Estimates of genetic parameters

Estimates for (co)variance components for birth weight and litter birth weight are presented in Table III. With the exception of direct variance, the estimates for maternal, direct maternal, phenotypic, environmental (co)variance components for litter birth weight were higher than corresponding estimates for birth weight. However, corresponding estimates for direct and maternal heritabilities for birth weight were higher. The direct and maternal heritability estimates were 0.61 and 0.32, 0.30 and 0.27 for birth weight and litter birth weight, respectively. Corresponding estimates for direct maternal genetic and phenotypic correlations were -0.48 and -0.65, and 0.28 and 0.57, respectively.

■ DISCUSSION

The least square estimates for BWT obtained in the present study were lower than reported estimates for the same breed (5). This may be attributed to differences in sample size and management systems. However, the significant effects of sex, birth type, parity,

Table II

Least squares means (standard error) of birth weight (BWT) and litter birth weight (LBWT) according to fixed effects

Effect	Num.	BWT	(SE)	Num.	LBWT	(SE)
μ	610	2.23	(0.06)	497	2.83	(0.11)
Sex		*			***	
Male	300	2.35	(0.07)	215	2.73	(0.25)
Female	310	2.28	(0.07)	223	2.64	(0.23
Mixed				59	3.97	(0.38)
Birth type		***			***	
Single	384	2.48	(0.07)	382	2.50	(0.20)
Double	226	2.03	(0.07)	115	3.96	(0.21)
Parity		**			*	
1	210	2.08	(0.22)	171	2.53	(0.33)
2	146	2.33	(0.23)	117	2.91	(0.42)
3	116	2.53	(0.17)	95	3.07	(0.40)
4	99	2.49	(0.18)	82	3.07	(0.26)
5	39	2.33	(0.25)	32	2.83	(0.45)
Season of birth		*			*	
1	191	2.36	(0.13)	190	3.03	(0.26)
2	179	2.34	(0.10)	113	2.79	(0.17)
3	240	2.25	(0.12)	194	2.77	(0.24)
Year of birth		*			*	
1994	190	2.08	(0.11)	135	2.82	(0.20)
1995	212	2.45	(0.10)	173	2.94	(0.33)
1996	208	2.37	(0.10)	189	2.75	(0.21)
Feed group		*			**	
S	262	2.34	(0.08)	209	2.89	(0.11)
ST	156	2.39	(0.09)	124	3.10	(0.12)
T	137	2.23	(0.10)	116	2.63	(0.12)
NST	55	2.10	(0.11)	48	2.41	(0.14)

μ: overall mean; S: supplementation group; ST: supplementation and treatment group; T: treated group; NST: no supplementation no treatment group
* $P < 0.5$; ** $P < 0.01$; *** $P < 0.001$-0.0001

Table III

(Co)variance components and heritabilities for direct and maternal components for birth weight (BWT) and litter birth weight (LBWT) for Fulbe sheep

Parameter	Birth weight	Litter birth weight
σ^2_a	2016.647	1536.634
σ^2_m	1046.054	1382.785
σ_{am}	-703.671	-940.267
σ^2_e	933.323	2945.870
σ^2_p	3313.352	5203.952
h^2_a	0.61	0.30
h^2_m	0.32	0.27
r_{am}	-0.48	-0.65
r_p	0.28	0.57

σ^2_a: direct additive variance; σ^2_m: maternal additive variance; σ_{am}: direct maternal covariance; σ^2_e : environmental variance; σ^2_p: total phenotypic variance; h^2_a: direct heritability; h^2_m : maternal heritability; r_{am}: direct maternal genetic correlation; r_p: direct maternal phenotypic correlation

season and year of birth have been reported for the breed (5). The significant season of birth effect on birth weight and litter birth weight can be attributed to seasonal variations associated with nutritional problems, climatic stress and incidence of diseases so pronounced in the area of study. These variations affect forage availability (9) given that the rainy season is usually a period associated with the growth of high nutritive forages. This favors the production of heavy lambs from ewes conceived during this season. Ewes that lambed during the cold dry or hot dry seasons could have conceived in the early or latter part of the rainy season. The fetus benefited from a better maternal (uterine) environment, as abundant and relatively rich rainy season pastures provided better nutrition to the ewe.

The supplementation and treatment of lambing ewes simply created a more favorable uterine environment for the fetus. The significant effect of parity on BWT may be attributed to the fact that primiparous ewes are still growing and they must provide for their own growth in addition to the fetal demand (9). With increase in parity, growth demands of the ewe decrease and as a result more is available for the fetus. Montgomery *et al.* (10) associate the increase of litter with the increase in parity to the fact that the increase in age and body weight causes an increase in the ovulation rate.

Estimates for direct heritability were higher than corresponding maternal estimates for both birth and litter birth weights. These high and moderate estimates of direct heritability indicated that there were distinct possibilities of improving birth weight and litter birth weight through selection of own performance. However, a high selection intensity for own performance might in the long run be detrimental to the maternal performance because of the high genetic antagonism between direct and maternal effects for birth and litter birth weights. Estimate of direct heritability (0.61) for birth weight in the present study was quite high compared to the reported estimate (0.35) for the same breed from the regression of the lamb birth weight on birth weight of the ewe (5). This estimate was also higher than those reported by Osinowo *et al.* (12), Bathaei and Leroy (1), Fall *et al.* (8), Strickberger (14), Djemali *et al.* (4), Inyangala *et al.* (9) and El Fadili *et al.* (7) for Yankasa, Mehraban Iranian fat-tailed, Djallonke, Shropshire, Barbarine, Dorper and Timahdite sheep breeds, respectively. Conversely, the estimate for maternal heritability (0.32) obtained in the present study was lower compared to estimates obtained for Timahdite and crossbred lambs in Morocco. Differences in the estimates might result from unwanted variations due to environmental differences, management differences, breed differences and influence of genotype and environmental interaction.

There are no reports in the literature on genetic and phenotypic correlations for the Fulbe sheep. However, the negative genetic correlation estimates (-0.48 and -0.65) reported in the present study were lower compared to those reported by El Fadili *et al.* (7). However, the high negative genetic correlation estimates indicated that direct selection for increase BWT and LBWT were associated with a decline in maternal performance. The phenotypic correlation between direct and maternal effects was moderate for the birth weight (0.28) and high for the litter birth weight (0.57), indicating that environmental factors contributed more positively to determine the litter birth weight than the birth weight.

■ CONCLUSION

Sex, season of birth, year of birth, birth type, parity and feed group significantly affected birth and litter birth weights. Heavier lambs or higher litter weights occurred in the cold and hot dry seasons. It may be therefore necessary to program exposing breeding ewes to rams at the end (September) and/or beginning (June) of the rainy season so that lambing (for higher birth weights) could take place in the cold or hot dry season. Conversely, to reduce high risk of dystocia (lower birth weights) the ewes could be exposed for rainy season lambing. Estimates for direct heritability were high for birth weight and moderate for litter birth weight. Estimates for genetic correlation between direct and maternal effects were high and negative. These indicate a high genetic antagonism between the direct and maternal effects.

Acknowledgments

The authors gratefully acknowledge the financial assistance from the Regional Small Ruminant Project for Cameroon and Chad. They also appreciate the contributions of Messrs J. Choupamom and C. Nassourou for data collection.

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Accepté le 04.02.2002

Résumé

Ebangi A.L., Njoya A., Ngo-Tama A.C., Awa D.N., Mbah D.A. Paramètres génétiques et phénotypiques des caractères du poids à la naissance chez les moutons Foulbé au Camroun

De 1993 à 1996 les données sur le poids à la naissance de 610 agneaux issus de 199 brebis Foulbé primipares, saillies au hasard par 21 béliers, ont été recueillies à la Station polyvalente de Recherche agricole pour le développement de Garoua. Les données ont été utilisées pour identifier et quantifier les facteurs affectant le poids à la naissance (PN) et le poids de la portée à la naissance (PPN), et pour obtenir les estimations des héritabilités directe et maternelle ainsi que les corrélations génétiques et phénotypiques entre les effets direct et maternel. Les résultats ont montré que, respectivement, 26,86 et 34,20 p. 100 de la variabilité du PN et du PPN étaient expliqués par le sexe, la saison et l'année de naissance, la parité, le type de naissance et le type d'aliment. Des agneaux plus lourds (2,36 kg) ont été produits pendant la saison sèche froide (octobre à janvier). Les portées mixtes avaient des poids significativement plus élevés (3,97 kg) que celles composées uniquement de mâles (2,73 kg) ou de femelles (2,64 kg). Les estimations de l'héritabilité directe et maternelle ont été respectivement de 0,61 et 0,32 pour le PN et de 0,30 et 0,27 pour le PPN. Les estimations pour les corrélations génétiques et phénotypiques entre les effets direct et maternel ont été respectivement de -0,48 et 0,28 pour le PN, et de -0,65 et 0,57 pour le PPN. Toutefois, en raison des estimations élevées mais négatives de la corrélation génétique, la sélection à long terme sur la performance directe portant sur le PN ou le PPN affecte de façon négative la performance maternelle.

Mots-clés : Ovin - Mouton Foulbé - Poids à la naissance - Héritabilité - Paramètre génétique - Corrélation génétique - Cameroun.

Resumen

Ebangi A.L., Njoya A., Ngo-Tama A.C., Awa D.N., Mbah D.A. Parámetros genéticos y fenotípicos de los caracteres de peso al nacimiento en ovejas Fulbé en Camerún

Se recolectaron datos sobre el peso al nacimiento de 610 corderos producidos por el cruce al azar de 21 corderos con 199 ovejas Fulbé, entre 1993 y 1996, en el Instituto de Investigación Agrícola para el Desarrollo, Estación de Investigación de Garua. Los datos se utilizaron par identificar y cuantificar los factores que afectan el peso al nacimiento (BWT) y peso al nacimiento de la camada (LBWT), así como para estimar caracteres hereditarios directos y maternos, correlaciones fenotípicas y genéticas entre los efectos directos y maternos. Los resultados indican que una variabilidad de 26,86% en el BWT y de 34,20% en el LBWT fue provocada por el sexo, estación de nacimiento, año de nacimiento, paridad, tipo de parto y grupo alimenticio. Los corderos más pesados (2,36 kg) fueron producidos durante la estación seca y fría (octubre a enero). Las camadas mixtas (3,97 kg) presentaron pesos significativamente más altos que las camadas compuestas por solo machos (2,73 kg) o solo hembras (2,64 kg). Las estimaciones para la herencia directa y materna fueron de 0,61 y 0,32 para BWT y 0,30 y 0,27 para LBWT. Las estimaciones para las correlaciones fenotípicas y genotípicas entre los efectos directo y materno fueron de -0,48 y 0,28 para BWT y -0,65 y 0,57 para LBWT. Debido a las altas estimaciones negativas para la correlación genética, la selección a largo plazo sobre el rendimiento propio, sea para BWT o LBWT afectará adversamente el rendimiento materno.

Palabras clave: Ovino Foulbe - Peso al nacimiento - Heredabilidad - Parámetro genético - Correlación genética - Camerún.