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Use of structural equation models to evaluate growth of Blanco-Orejinegro sires undergoing performance tests

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ADDITIONAL KEYWORDS

Genetic Improvement.
Multivariate Analysis.
Sire selection.
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SUMMARY

A performance test (PT) in the Blanco-Orejinegro (BON) cattle breed comprises four consecutive phases: grazing (FP), mass supplementation (FSM), group supplementation (FSG), and individual supplementation (FSI). The effect of each phase on the others should also be considered. The objective of this study was to analyze growth of BON males undergoing PT. Information from six PTs involving 154 BON males was used. Weight gain was used to analyze the relationship between phases trough four structural equation models (SEM). The models were compared through goodness of fit and also using convergent and discriminant validity criteria. The best model considered the relationships between FP, the fusion of FSM and FSG and the FSI, with factorial loads greater than 0.90. In conclusion, tests phases have an effect on animal growth, which may alter the results during selection of elite animals.

Uso de modelos de ecuaciones estructurales para evaluar el crecimiento de machos de Blanco-Orejinegro bajo control de rendimientos

RESUMEN

En la raza Blanco-orejinegro (BON) se realizan pruebas de desempeño (PD), las cuales contemplan cuatro fases consecutivas: pastoreo (FP), suplementación masiva (FSM), suplementación grupal (FSG) y suplementación individual (FSI), por lo que debería también estimarse el efecto de cada una de las fases sobre las demás. El objetivo de este trabajo fue analizar el crecimiento de machos BON sometidos a PD. Se utilizó información de seis PD de 154 machos BON y la relación de las fases se analizó mediante la variable ganancia de peso utilizando cuatro modelos de ecuaciones estructurales (SEM), los cuales fueron comparados con los criterios de bondad de ajuste y de validez convergente y discriminante. El mejor modelo fue el que consideró las relaciones entre FP, la fusión de FSM y FSG y la FSI, con cargas factoriales mayores de 0.90. Las diferentes fases de las pruebas tienen efecto en el crecimiento de los de los animales lo cual puede alterar los resultados en la selección de los animales elite.

PALABRAS CLAVE SUPLEMENTARIAS

Ganado de carne.
Mejoramiento genético.
Análisis multivariado.
Selección de reproductores.

INFORMATION

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INTRODUCTION

Blanco-Orejinegro (BON) cattle is a Colombian creole breed which has been kept under conservation since 1941 (Martinez et al. 2012). Most studies conducted on this breed have been aimed to its conservation. Recently, the interest has focused on the productive characterization and the processes of genetic selection of sires with superior growth.

Performance test (PT) are widely used in several breeds for selecting animals. An advantage of PT is that the own performance of the animal is evaluated for medium to high heritability traits. Breeder selection by PT of grazing BON animals began in 2008 and are conducted in phases with animals undergoing different feeding strategies. Selection of individuals involves calculating an index (IT) that use standardized characteristics weighed according to their importance (Quiceno et al. 2012). The residual effect and relationships between phases are not considered in the calculation of IT. This constraint urges to search for alternatives to estimate this effect. Structural equation models (SEM), which allow to calculate the effect between unmeasured variables, become a potential tool to analyze these results.

SEMs, a family of multivariate models, use observed variables (representing to rectangles in the figure) that generate latent variables (representing to ovals in the figure), which can present causal relationships. These models allow establishing causal relationships between latent variables (Lance et al. 2000; Pérez et al. 2013). They also allow to analyze growth using the latent variable growth model (LGM) structure. The latent variables in LGM can be the "intercept" -which represents the initial state- and the "slope" -representing the rate of change over time (Duncan and Duncan 2009; McArdle and Epstein 1987). Advantages of the LGM include its flexibility, the ability to model a wide range of growth functions, and that measurements can take different intervals (Curran and Hussong 2003; Duncan and Duncan 2009; Ghisletta and Mcardle 2009). The objective of this study was to study growth in BON sires undergoing performance tests.

MATERIAL AND METHODS

The PTs were conducted at El Nus Research Center (San Roque Municipality, Antioquia, Colombia; North 06° 29′ 43.04″ and West 74° 50′ 24.6″), between 800 and 1250 meters above sea level. Average temperature: 23.2°C. Average rainfall: 2500 mm/year.

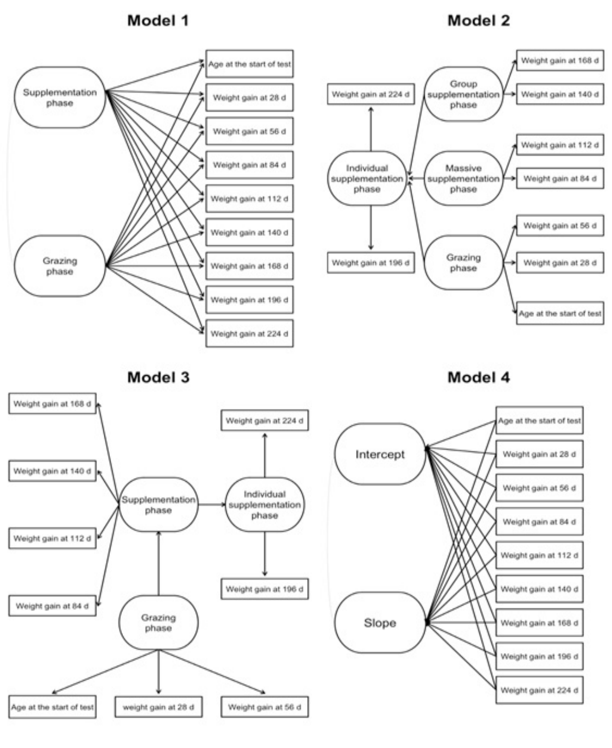

Figure 1. Structural equation models proposed for the growth analysis of BON males undergoing performance tests (Modelos de ecuaciones estructurales propuestos para el análisis de crecimiento de machos BON sometidos a pruebas de desempeño). Own elaboration.

Information from six PTs was used. A total of 154 males aged between 12.0 and 21.7 months, belonging to 33 farms, participated. The males that did not meet BON breed standards were disregarded during the first phenotypic selection. A general inspection was performed to verify good health of the animals. Then, they were vermifuged with ivermectin dosed according to body weight.

The animals were grazing on rotational stripes of B. decumbens, braquipara (B. plantaginea) and stargrass (Cynodon nlenfluensis) during the tests. Animal weightings were conducted at the same hours on 28-d intervals, after one hour´s rest. The PTs were conducted in four consecutive feeding phases after an adaptation period of 28 days. The feeding regime during each phase lasted 56 days, with concentrate-feed supplementation as follows: Grazing phase (FP; fed only grass), Mass supplementation phase (FSM; 1 kg concentrate/animal/day), Group supplementation phase (FSG; 1.5 kg concentrate/animal/day), and Individual supplementation phase (FSI; 2.0 kg concentrate/animal/day). The total duration of the test was 224 days. The concentrate (consisting of 80% ground corn, 15% extruded ground soybeans, and 5% molasses) had 88.5% dry matter, with 119 g protein and 2.85 Mcal metabolizable energy/kg dry matter.

Weight gain during each 28-day weighing interval was the analyzed variable for 224 days of PT duration. Three reflective structural models and a formative-type latent growth modeling (LGM) were used to analyze growth during the PT (**Figure 1**).

Model 1 (M1) was obtained from an exploratory analysis, and its hypothesis was:

H1 = "The phases of the test are divided into two, and are independent"

Model 2 (M2) included all four test phases and its hypotheses were:

H1 = "The test phases are 4"

H2 = "FP affects FSM"

H3 = "FSM affects FSG"

H4 = "FSP, FSM and FSG affect FSI".

Model 3 (M3) considered phases FP, FSI, and FS (which is a fusion of FSM and FSG with the aim of of simplify the management), and its hypotheses were:

H1 = "FP affects FS"

H2 = "FS affects FSI"

Model 4 (M4) was an LGM that included two factors representing patterns of weight change (y), as follows:

The intercept (β0), which represents the (y) value at time (t) zero.

The slope (β1), which represents weight change rate per unit of (t) variation. (Duncan and Duncan, 2009; McArdle and Epstein, 1987; Preacher et al., 2008).

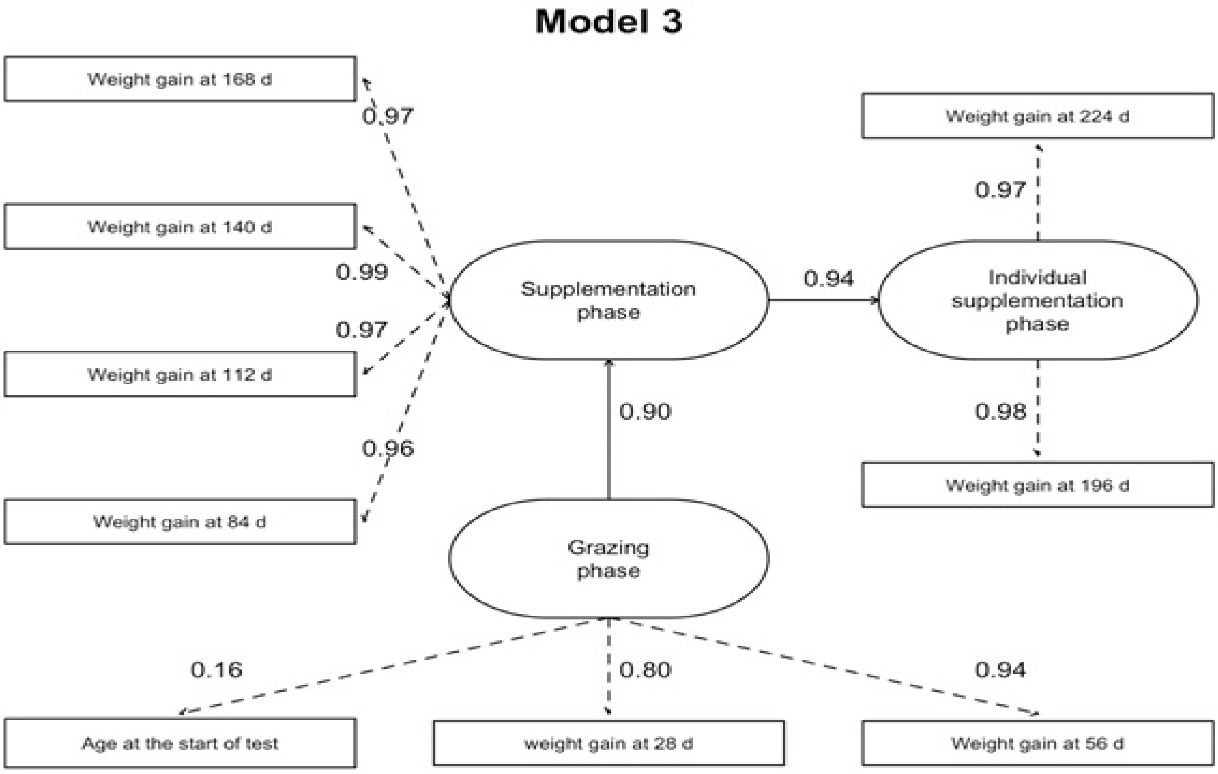

Figure 2. Structural model of cumulative weight gain during three management phases of BON males subjected to performance tests (Modelo estructural de ganancia acumulada de peso en tres fases de manejo para machos BON sometidos a pruebas de desempeño). Own elaboration.

To choose the best model, the following criteria were taken into account: Chi-square (X2), Normed fit index (NFI), Non-normed fit index (NNFI, also called the Tucker-Lewis index: TLI), Comparative fit index (CFI), Goodness-of-fit index (GFI), Root mean square error approximation (RMSEA) and standardized root mean square (SRMR) (Lin et al. 2017).

The animals were classified for each PT according to the predicted value of the FSI, and compared with the classification obtained from total weight gain, using Spearman correlations.

RESULTS

The best fit values were observed in M3. The X2, NFI, NNFI, and CFI values were 294.34, 0.89, 0.85, and 0.89, respectively. The estimated RMSEA and SRMR were 0.26 and 0.08, respectively. Estimated Cronbach's alphas were 0.45, 0.98, and 0.97 for FP, FS, and FSI, respectively. The structure model is seen in Figure 2.

The factor loads were high for the cumulative weight gains, ranging from 0.80 to 0.99. The average factor loads were between 0.63 and 0.98 (**Table I**).

The composite variance indices (CVI) for FP, FS and FSI were than 0.7. The extracted variance index (EVI) for FP was 0.50, and it was greater than 0.95 for FS and FSI.

The results validate the H2 hypotheses: FP positively influenced animal weight in FS ($p < 0.05$) and it had a positive indirect effect on FSI. H3 = FS positively affected weight gain in FSI ($p < 0.05$). The phase with the highest total effect on FSI (the last phase of the test) was FS, while FP was the phase with the least effect. The direct, indirect and total effects are presented in **Table II**.

The estimated Spearman correlations between FSI and cumulative weight gains were greater than 0.9 in all tests (**Figure 3**).

DISCUSSION

The best fit values were observed in M3, indicating that this model best described PT in BON cattle. The X2, NFI, NNFI, and CFI values, indicating proper goodness-of-fit, as reported by Hoe (2008), Hooper et al. (2008) and Hormigo (2014). The estimated RMSEA was high considering that the maximum accepted value for RMSEA for this error is 0.1, however, the SRMR index was acceptable (0.08). All the indices should be taking into account. Correct models could be rejected when only the RMSEA is used, since it is sensitive to degrees of freedom and sample size.

Differing from the exploratory factor analysis that proposed two phases for M1 (FP and FS), the four phases for M2 (FP, FSM, FSG and FSI) and M4 LGM, the results showed that the PT phases in BON cattle are three, as proposed in M3, indicating that FSM and FSG can be handled as a single phase. This facilitate the

Table I. Factor loads for the structural model of performance tests in BON cattle (Cargas factoriales para el modelo estructural de pruebas de desempeño en ganado BON).

Phase	Mean factor load	Variable	Factor load
Grazing	0.63	weight at start of test	0.16
		weight gain to 28 d	0.80
Supplementation	0.98	weight gain to 56 d	0.94
		weight gain to 84 d	0.96
		weight gain to 112 d	0.97
		weight gain to 140 d	0.99
		weight gain to 168 d	0.97
Individual supplementation	0.97	weight gain to 196 d	0.98
		weight gain to 224 d	0.97

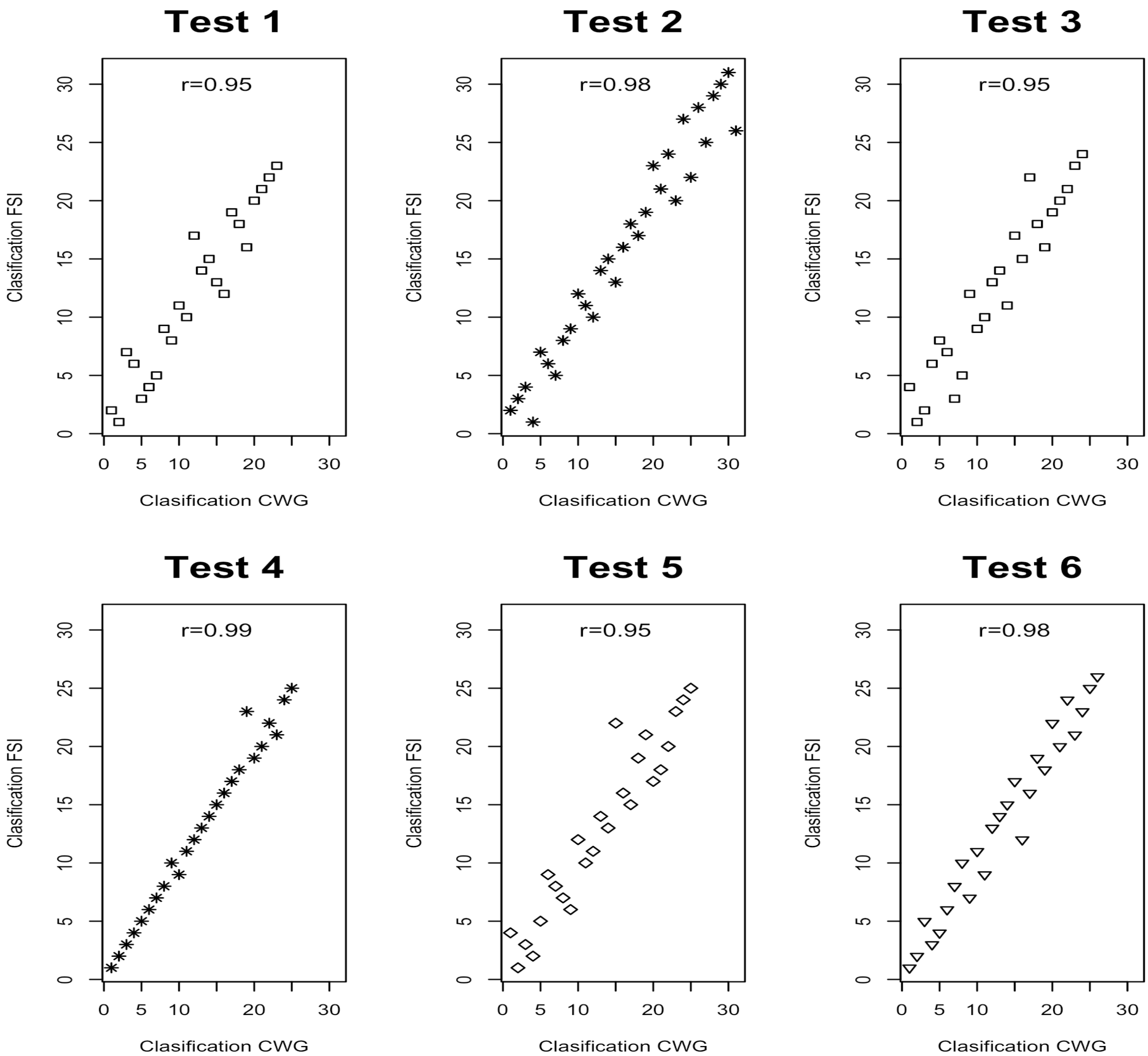

Figure 3. Relationship (r= Spearman correlation) between classification by cummulative weight gain (CWG) and estimated value for individual supplementation phase (FSI) by the structural equation model (SEM) in BON males submitted to performance tests (Relación (r=correlación de Spearman) entre la clasificación por ganancia de peso acumulada (CWG) y el valor estimado para la fase de suplementación individual (FSI) por el modelo de ecuación estructural (SEM) en machos BON sometidos a pruebas de desempeño. Own elaboration.

Table II. Factor loads of the grazing and supplementation phases in relation to the individual supplementation phase during the performance tests of BON males (Cargas factoriales de las fases de pastoreo y suplementación en relación con la fase de suplementación individual durante las pruebas de desempeño de machos BON).

Phase	Direct	Indirect	Total
Grazing	0.00	0.84	0.84
Massive and group supplementation	0.94	0.00	0.94

management of PT and eliminate the effect of different phase management on animal growth.

Cronbach's alphas for latent variables FS and FSI, is in agreement with Nunnally and Bernstein (1994), who stated that this value should be higher than 0.7, indicating that the set of observed variables is measuring the same latent variable.

These results the factor loads suggest that the variables belong to the assigned factor (Bagozzi and Yi 1988). The factor load at age 0 was low, indicating that age at the start of the test did not have a significant effect on animal performance in FP, which affected the results of Cronbach's alpha and extracted variance (IVE). Nevertheless, this variable was maintained in the model due to its importance in PT.

The composite variance indices (CVI) for FP, FS and FSI were greater, indicating that the convergent validity criterion was met (Fornell and Larcker 1981). The extracted variance index (EVI) for FP was low, mainly influenced by the low factor load of age at the starting of the test, and it was greater than for FS and FSI, indicating discriminant validity.

The results validate the hypotheses the M3. These results suggest that the animals starting with high weight gains in FP continued this trend in the following phases. This is in agreement with the report by Selemani and Eik (2016) who obtained higher profits for animals fed a combination of grazing and supplementation compared with animals fed only pastures. According to those researchers this result may be due to the concentration of nutrients in the supplement and a decrease in energy expenditure for forage search.

The estimated Spearman correlations between FSI and cumulative weight gains were higher than 0.9 in all tests. However, reclassification of the best animals (animals selected for semen collection) was found in five of the six PTs. This may be due to the fact that M3 corrects the growth values in FSI considering the causal relationships between test phases.

CONCLUSIONS

The PTs of BON males have three differentiated phases, as evidenced using a SEM model. Causal relationships among these phases affect animal growth. This effect can cause a reclassification of elite males due to performance changes in each phase.

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