GENETIC PARAMETERS AND SELECTION INDEXES FOR SOME PRODUCTIVE AND REPRODUCTIVE CHARACTERISTICS IN PELIBUEY EWES IN SOUTHEASTERN MEXICO†

[PARÁMETROS GENÉTICOS E ÍNDICES DE SELECCIÓN PARA ALGUNAS CARACTERÍSTICAS PRODUCTIVAS Y REPRODUCTIVAS EN OVEJAS PELIBUEY EN EL SURESTE DE MÉXICO]

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SUMMARY

The aim was to estimate the genetics parameters for litter size at lambing (LSB), litter size at weaning (LSW), litter weight at lambing (LWB), litter weight at weaning adjusted to 60 days (LW60) and lambing interval (LI) in ewe Pelibuey sheep and to compare selection indexes. Heritabilities and genetic and phenotypic correlations for the characteristics were calculated using animal models. Sixteen indexes (IS1-IS16) based on the desired genetic gain methodology were compared. The indexes were combinations of LW60 with LSB, LSW and LWB and LI. Heritabilities for LSB, LSW, LWB, LW60 and LI, were 0.07, 0.02, 0.08, 0.09 and 0.03, respectively. Genetic correlations varied from 0 to 0.79, whilst the phenotypic correlations varied from -0.07 to 0.62. The best index based on relative efficiency of an index was 2.31*LSB+0.24*LW60. In conclusion, the heritabilities estimated were low and the best selection index included LSB and LW60. The number and type of characteristics contained in the index had an impact on genetic progress.
Keywords: Pelibuey; heritability; genetic correlation; desired genetic gain; genetic progress.

RESUMEN

El objetivo fue estimar los parámetros genéticos para tamaño de camada al parto (LSB), tamaño de camada al destete (LSW), peso de camada al parto (LWB), peso de camada al destete ajustado a 60 días (LW60) y el intervalo de parto (LI) en ovejas de Pelibuey y comparar índices de selección. Heredabilidades y correlaciones genéticas y fenotípicas para las características fueron calculadas usando modelos animales. Dieciséis índices (IS1-IS16) basados en la metodología de ganancia genética deseada fueron comparados. Los índices fueron combinaciones de LW60 con LSB, LSW, LWB y LI. Las heredabilidades para LSB, LSW, LWB, LW60 y LI fueron 0.07, 0.02, 0.08, 0.09 y 0.03, respectivamente. Las correlaciones genéticas variaron de 0 a 0.79, mientras que las correlaciones fenotípicas variaron de -0.07 a 0.62. El mejor índice basado en la eficiencia relativa de un índice fue 2.31*LSB + 0.24*LW60. En conclusión, las heredabilidades estimadas fueron bajas y el mejor índice de selección incluyó LSB y LW60. El número y el tipo de rasgos contenidos en el índice influyeron en el progreso genético.
Palabras clave: Pelibuey; heredabilidad; correlación genética; ganancia genética deseada; progreso genético.

INTRODUCTION

In the tropics of Mexico, Pelibuey sheep is kept as purebred or crossbred, playing a significant maternal role for meat production (Góngora *et al.,* 2010; Magaña-Monforte *et al.,* 2013; Hinojosa-Cuéllar *et al.*, 2015). Animal performance can be improved by better management and genetic improvement, the latter being slow but permanent and cumulative (Connington *et al.,* 2001). The replacement of both rams and ewes, in commercial or breeding flocks, in the tropics is carried out by the farmer based on the appearance of the animal without regard to productive and reproductive performance.

In lamb production systems, some economical important characteristics identified are litter weight at birth and at weaning, lamb survival, fertility and prolificacy (Snowder and Fogarty, 2009; Macías-Cruz *et al.,* 2009; Lôbo *et al.*, 2012; Magaña-Monforte *et al.,* 2013; Lambeye *et al.*, 2014). To improve lamb production via genetic approach, estimation of genetic parameters is necessary, as they are employed to predict direct and correlated responses to selection and construction of selection indexes (Snowder, 2008; Byrne *et al.,* 2013; Boujenane *et al.*, 2013). Genetic parameters are also used to identify outstanding or high genetic merit animals, capable of producing efficiently and transmitting their potential to the offspring. Some authors (Safari *et al.,* 2005; Snowder, 2008; Vatankhah and Talebi, 2008; Boujanane *et al.,* 2013) estimated heritability values in other sheep breeds. However, in Pelibuey sheep information available is

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scarce and is on pre-weaning characteristics (Carrillo *et al.,* 1993; Pérez-Ramírez *et al.,* 2003; Hinojosa-Cuellar *et al.,* 2012; Domínguez-Viveros and Rodríguez-Almeida, 2014).

Selection can be set for a single characteristic; however, efficient lamb production depends on the optimal combination of productive and reproductive characteristics of economic importance. Therefore, is desirable to select animals with the best combination of these characteristics with the aim of improving the total genetic merit. This could be done by using selection indexes. The relative economic value of each single characteristic is one of the basic requirements of a selection index (Hazel *et al.*, 1943; Hazel *et al.,* 1994); however, the estimation of relative economic values is a complex process that changes rapidly in the market. To avoid this problem, alternative methodologies have been developed, such as the selection for desired genetic gain proposed by Yamada et al. (1975). This approach replaces the economic value for a real and possible amount to be improve for each trait such as did Chi-Colli *et al.,* (2016) and Segura-Correa *et al.,* (2017) with Braunvieh cattle in Mexico.

Some authors in other countries (Conington *et al.,* 2001, Solomon *et al.,* 2010, Márquez *et al.,* 2012 and Lembeye *et al.,* 2014) have developed selection indexes in different breeds of sheep with their respective methodologies and traits of economic importance. However, there are no proposals for selection indexes for the Pelibuey hair sheep in Mexico.

The objectives were to calculate genetic parameters for some productive and reproductive characteristics of Pelibuey sheep, and to compare sixteen selection indexes for some productive and reproductive economical important characteristics of Pelibuey sheep, using the methodology of the desired genetic gain.

MATERIALS AND METHODS

Location

The present study was performed in a breeder Pelibuey farm, in Yucatan, Mexico. The region is warm and, humid with rain mainly in summer (Aw0), the annual average temperature is 26.0 ° C and the average annual rainfall 900 mm (CIBCEC, 2012).

Management

Replacement ewes was chosen at weaning, approximately 60 days of age, based on its phenotypic appearance, and then, on breed conformation and body development at 10 months of age. Females were bred in three periods of the year that were January-February, August-September and November-December. Additionally, estrus in non-pregnant ewes was synchronized 60 days after the end of the breeding period. Pregnancy diagnosis was carried using an ultrasound.

Animals were grazed in *Brachiaria brizhantha* grass and supplemented, during the critical months with 300 g of a commercial feed and 10 g of minerals. Weaning was at approximately 60 days. During that period, lambs were given a diet with 20% protein, ad libitum. Regarding health management, deworming and vaccination against Clostridia and Pasteurella were carried out every six months.

Data

The initial sheep flock began in 2000, with 50 crossbred Pelibuey x Katahdin ewes (F1 and ¾ Pelibuey) mated to Pelibuey rams in a semi-intensive fattening system. In 2003, 50 pure Pelibuey females were purchase from different parts of Mexico, changing the course of production toward the sale of pure Pelibuey rams. The new flock was managed in 32 grazing hectares, with 2 hectares for sheep production halls. The farm had electricity, water supply, irrigation system and technological facilities with capacity to maintain up to 1500 animals in different stages of production.

Records of 814 lambings of 409 Pelibuey ewes registered from 2007 to 2013, were used. The database included the ewe, sire and dam tags, year of lambing, season of lambing, number of parities, litter size at lambing (LSB), litter size at weaning (LSW), litter weight at lambing (LWB), litter weight adjusted at 60 days (LW60) and lambing interval (LI).

Because some years had limited number of data per year, those were combined in four groups (2007-2008, 2009-2010, 2011-2012 and 2013). In addition, ewes with more than 5 parities were assigned to a single group. Three seasons, based on temperature and rainfall distribution were generated: dry season (February May), rainy season (June to September) and windy and wet season (October to January)

Statistical analysis

Four-hundred and nine ewes (n = 814 litters), the progeny of 46 sires and 195 dam - were evaluated. Prior to the estimation of genetic parameters, non-genetic effects on the characteristics assessed were determined using the SAS statistical software (SAS, 2002). To estimate the heritabilities and standard errors of the characteristics, the MTDFREML software (Boldman *et al.,* 1995) was employed using a univariate animal model. The statistical model in matrix notation was:

$$Y = Xb + Za + \varepsilon$$

Where:

Y= Vector of observations for each characteristic

b= Vector of effects taken as fixed
a= Vector of direct additive genetic random effects
X and Z = Matrices of incidences associated with fixed and direct additive effects, respectively.
Ɛ= Vector of residual effects

The effects considered fixed were year of lambing, season of lambing and parity number for LSB, and in addition, litter size at lambing for LSW, LWB, LW60 and LI. Heritabilities and genetic and phenotypic correlations were estimated using bivariate animal models, similar to that for the univariate model. The estimates obtained in univariate analysis were used as initial values in the bivariate analyzes. Only the additive genetic component was included due to data structure available. The heritabilities here obtained were zero, therefore, for the construction of the indexes, the (co)variance for LI, LWB and LW60 used were obtained from the mean heritabilities reported in the literature (Mokhtari *et al.*, 2010; Rashidi *et al.*, 2011; Boujename *et al.*, 2013; Zishiri *et al.*, 2013; Schmidova *et al.*, 2014). Genetic and phenotypic variances-covariances used for the construction of the indices are shown in Table 1. The genetic variances (σ^2G) and standard deviation (σG) were calculated as: $\sigma^2_G= h^2 * \sigma^2_P$; where h^2 is the heritability of the characteristic and σ^2P is the phenotypic variance. Genetic covariances used were derived by multiplying the genetic correlation by the respective genetic standard deviation: $Covxy = rxy*\sigma x* \sigma y$.
Selection indices were built following the desired genetic gain methodology proposed by Yamada *et al*. (1975). Matrix operations were carried out in 2007 Excel ® software. For each trait, the improvement objective considered was 5% of the average value of the trait (Table 2).

Sixteen selection indexes (IS1 – IS16) were evaluated, LW60 by itself, and in combination with LI, LSB, LSW or LWB. The number of generations to allow genetic progress was determined by the equation:

$$q = (i_I/\delta_I)=\frac{\sqrt{b'Pb}}{iI}$$

Where:

q= the number of generations needed to get the desired gain
iI= is the differential of standardized selection (selection intensity) of the index and δ_I is the standard deviation of the index.

A selection intensity of 30% was considered, which corresponds to a value of 1.16 (Falconer and Mackay, 2006).

The index efficiency was calculated dividing the sum of the proportion that each characteristic reached, with respect to the genetic gain desired, between the number of generations:

$$\Delta I = [(GP_{LI}/DG_{LI}) + (GP_{LSB}/DG_{LSB}) + (GP_{LSW}/DG_{LSWD}) + (GP_{LSW}/DG_{LSW}) + (GP_{LWWA}/DG_{LWWA})] / q$$

Where:

ΔI= the efficiency of each index,
GP= represents the genetic progress achieved for each trait
DG= refers to the desired genetic gain of each trait and "q" is the number of generations.

To determine the best index, the relative efficiency (RE) of each index was compared with respect to the index that included the five characteristics (ΔI_{S1})
RE= (ΔI / ΔI_{S1}).

RESULTS

The heritabilities estimated in this study were close zero (Table 3); and genetic correlations varied from 0 to 0.79, whilst the phenotypic correlations varied from -0.07 to 0.62 (Table 4). The genetic progress achieved for each characteristic is shown in Table 5. The desired gain ranged from 1.68 to 16.78 generations, depending on the trait and number of traits included in the selection index. With regard to the efficiency of each index, IS13 and IS15, made up of two characteristics, were the best, followed by LW60 alone (Table 6).

Table 1. Heritabilities (diagonal), genetic (above the diagonal) and phenotypic (below the diagonal) correlations of some characteristics of Pelibuey ewes under tropical conditions.

Characteristic*		LI	LSB	LSW	LBW	LWWA
	Variance	157.91	0.02820	0.00179	0.04467	4.17330
LI	5719.3	0.0300	0.00063	0.00021	0.00053	0.02567
LSB	0.4028	0.3716	0.07000	0.00057	0.02804	0.08233
LSW	0.0843	- 0.1367	0.05769	0.02000	0.00018	0.05877
LBW	0.5584	0.2110	0.16753	0.03671	0.08000	0.06908
LW60	46.372	- 34.517	0.26677	1.20540	2.13183	0.09000

*LI= Lambing interval, LSB = Litter size at lambing, LSW = Litter size at weaning, LBW = Litter weight at lambing, LW60 = Litter weaning weight adjusted to 60 days of age.

Table 2. Means and desired genetic gain for each characteristic.

Characteristic*	Mean	Desired Genetic Gain
LI (days)	264.9	-13.24
LSB (number)	1.70	0.085
LSW (number)	1.61	0.080
LBW (kg)	4.53	0.226
LW60 (kg)	24.46	1.2

*LI= Lambing interval, LSB = Litter size at lambing, LSW = Litter size at weaning, LBW = Litter weight at lambing, LW60 = Litter weaning weight adjusted to 60 days of age.

Table 3. Variance components, heritability (h^2) with standard error (SE) of reproductive and productive characteristics of Pelibuey ewes.

Characteristic*	σ^2 additive	σ^2 phenotypic	h^2	SE
LI	157.91	5719.34	0.03	0.07
LSB	0.00001	0.40282	0.00	0.02
LSW	0.00179	0.08428	0.02	0.02
LWB	0.00002	0.55837	0.00	0.02
LW60	0.00021	46.37	0.00	0.03

* LI= lambing interval, LSB= litter size at lambing, LSW= litter size at weaning, WB= litter weight at lambing, LW60= litter weight at weaning adjusted at 60 days.

Table 4. Genetic (above the diagonal) and phenotypic correlations (below the diagonal) between reproductive and productive characteristics of Pelibuey ewes.

Characteristic*	LI	LSB	LSW	LWB	LW60
LI	-	0.00	0.00	0.00	0.00
LSB	0.01	-	0.08	0.79	0.24
LSW	- 0.01	0.30	-	0.02	0.68
LWB	0.004	0.33	0.17	-	0.16
LW60	- 0.07	0.06	0.62	0.42	-

*LI= lambing interval, LSB= litter size at lambing, LSW= litter size at weaning, LWB= litter weight at lambing, LWWA= litter weight at weaning adjusted at 60 days.

Table 5. Index coefficients (bi), genetic progress (GP) and generations (q) using indexes with different numbers of reproductive and productive traits*.

Index	b_{LI}	b_{LSB}	b_{LSW}	b_{LBW}	b_{LW60}	PG_{LI}	PG_{LSB}	PG_{LSW}	PG_{LBW}	PG_{LW60}	q
I_{S1}	-0.084	-5.63	70.96	9.48	-0.757	-13.24	0.085	0.081	0.226	1.2	16.78
I_{S2}	-0.084	3.84	68.96		-0.758	-13.24	0.085	0.081	0.067	1.2	16.65
I_{S3}	-0.084	-6.35		8.63	0.271	-13.24	0.085	0.014	0.226	1.2	8.30
I_{S4}	-0.084		71.58	6.04	-0.820	-13.24	0.14	0.081	0.226	1.2	17.01
I_{S5}		-5.63	70.98	9.48	-0.758	-0.003	0.085	0.081	0.226	1.2	15.93
I_{S6}	-0.084	2.31			0.243	-13.24	0.085	0.015	0.081	1.2	5.89
I_{S7}	-0.084		66.59		-0.649	-13.24	-0.015	0.081	-0.033	1.2	15.58
I_{S8}	-0.084			4.73	0.209	-13.24	0.149	0.013	0.226	1.2	6.68
I_{S9}		3.84	68.97		-0.75	-0.003	0.085	0.081	0.067	1.2	15.81
I_{S10}		-6.35		8.63	0.27	0.007	0.085	0.014	0.226	1.2	6.21
I_{S11}			71.60	6.04	-0.82	-0.003	0.14	0.081	0.226	1.2	16.18
I_{S12}	-0.084				0.288	-13.24	0.024	0.017	0.019	1.2	5.83
I_{S13}		2.31			0.242	0.007	0.085	0,015	0.081	1.2	1.95
I_{S14}			6.,61		-0.650	-0.003	-0.015	0.081	-0.033	1.2	14.65
I_{S15}				4.73	0.209	0.008	0.15	0.013	0.226	1.2	3.73
I_{S16}					0.287	0.007	0.024	0.016	0.019	1.2	1.68

*LI= Lambing interval, LSB = Litter size at lambing, LSW = Litter size at weaning, LBW = Litter weight at lambing, LW60 = Litter weaning weight adjusted to 60 days of age.

Table 6. Efficiency value (ΔI) and relative efficiency (RE) index formed with different numbers of reproductive and productive characteristics.

Índices	ΔI	RE
I_{S1}	0.298	1
I_{S2}	0.258	0.87
I_{S3}	0.499	1.67
I_{S4}	0.334	1.12
I_{S5}	0.251	0.84
I_{S6}	0.603	2.02
I_{S7}	0.171	0.57
I_{S8}	0.737	2.47
I_{S9}	0.208	0.70
I_{S10}	0.510	1.71
I_{S11}	0.288	0.97
I_{S12}	0.441	1.48
I_{S13}	1.303	4.37
I_{S14}	0.114	0.38
I_{S15}	1.050	3.52
I_{S16}	0.927	3.11

DISCUSSION

The knowledge of genetic parameters such as heritabilities and genetic correlations is important, for the construction of selection indexes and for the design and implementation of genetic improvement programs, as well as to measure the genetic progress achieved.

Heritabilities

The heritability estimated for LI was 0.03, which is close to the value of 0.01 obtained by Zishiri *et al.* (2013) in Dorper ewes, and the value of zero reported by Shiotsuki *et al.* (2014) in Morada Nova ewes.

Heritabilities for LSB, LSW, LWB and LW60 varied from 0.00 to 0.02, being similar to the estimates reported by Bülent *et al.* (2005) in Turkish Merino ewes with heritabilities of 0.05, 0.04, 0.04 and 0.02, for the same traits in that order. However, the values obtained are lower than that estimated by Vatankhah and Talebi (2008) in ewes Lori-Bakhtiarii with heritabilities of 0.10, 0.04, 0.23 and 0.15, respectively. More recent publications, Schmidova *et al.* (2014) in ewes of different breeds (Charollais, Romney, Merinolandschaf, Romanov, Suffolk, Texel and Sumava) calculated heritabilities for LSB of 0.06 to 0.11. On the other hand, Boujename *et al.* (2013) calculated heritabilities of 0.09, 0.11, 0.10 and 0.10 for LSB, LSW, LWB and litter weaning weight, respectively.

The differences between the heritability estimates could be due to ewe breed, genetic variation within populations, and the method of estimation of parameters. However, the heritabilities in this study and those reported in the literature, are low denoting greater environmental influence on the traits studied; therefore, a significant response to selection is not expected in the short term. In other words, the implications of low heritabilities for the characteristics to be improved are that heritabilities values close to zero indicates that poor genetic gain in animal breeding programs by selection is expected. Hence, an alternative for genetic improvement of the traits here studied could be trough crosses with other breeds. Therefore, the magnitude of the heritability is a tool for taken decisions about, which scheme of genetic improvement is the best.

Correlations

Correlations (Genetic and phenotypic) between LI and the other characteristics were low, being zero for the genetic and -0.07 to 0.004 for the phenotypic ones. The foregoing indicates that selection based on LI would not affect the other characteristics. This mean that selection for LI does not affect the other characteristics.

The estimated genetic correlations between LSB, LSW, LWB and LW60 characteristics varied from 0.02 to 0.79 whilst the phenotypic correlations varied from 0.06 to 0.62, which are within the interval of values reported by Rosati *et al.* (2002), Mohammad *et al.* (2012); but of low value than the estimates found by Boujename *et al.* (2013).

The high genetic correlation (0.68) between LSW Y LW60 indicates that the selection for one of the characteristics would produce a rise in another. However, characteristics with low heritabilities could be integrated into a selection index that will allow some degree of improvement by selection. Therefore, as mentioned above, for commercial flock Pelibuey the crossing of ewes from different breeds could be an alternative of genetic improvement.

Even though, genetic parameters estimated vary with time and geographical location, and are unique for the population and characteristic under study, the estimates obtained for a specific population give idea of possible values in populations under similar environmental conditions and management. In addition, the phenomenon of the genotype-environment interaction should be taken into consideration.

Selection indexes

In the present work different genetic progress were obtained according to the number of characteristics included in the index, which agree with Lembeye *et al.* (2014) who evaluated other characteristics in Merino sheep. The inclusion of the characteristic with the lowest h^2 (LSW = 0.02) in the indexes (IS1, IS2, IS4, IS5, IS7, IS9, IS11, IS14) increased the number of generations to achieve the desired genetic progress, which in turn were the least efficient per generation (Table 5). Solomon *et al.* (2010) obtained similar results when constructed indexes for ewes in traditional systems in which the inclusion of the LSW showed a slow genetic progress compared to the index in which, it was not included. This indicates the impact of heritability and genetic correlation values in an index. Therefore, the choice of the best selection index has important implication in breeding programs and expected response to multi-characteristics selection.

Finally, molecular genetics studies are becoming more popular and accessible; therefore, in the near future this discipline will have an important impact in the way genetic parameters are estimated, selection indexes constructed, and genetic evaluations and animal breeding programs are being made.

CONCLUSION

The low heritabilities for LSB, LSW, LWB, LW60 and LI suggest that these characteristics are more dependent on environmental factors than in the effect of genes, so to achieve some genetic progress by selection, the ideal would be to develop the best selection index. The number and type of traits included in the index had an impact on the genetic progress. The best index of selection included LSB and LW60 (Table 6).

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Conflict of interest statement

Authors declare they do not have any conflict of interest.

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