Genetics of growth traits in Bolivian llamas

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Abstract

The present study was carried out by the University of Hohenheim, Germany, the local NGO ASAR, Universidad Mayor de San Simón, Cochabamba, Bolivia and the University of Agricultural Sciences, Vienna, Austria. The study area is located in the High Andes of Bolivia, Department of Cochabamba, Province of Ayopaya.

In the study area two different types of llamas are found. Th´ampullis are regarded as wool-llamas with higher fleece yields and Kh´aras are more meat-oriented llamas. Aim of the study is to show differences in the development of body traits and body weight between these two types and between sexes. Growth curves for the five body measurements body weight (BW), height at withers (HW), body length (BL), chest circumference (CC) and abdomen circumference (AC) were described with the nonlinear Brody function (Fitzhugh 1976). Differences in the rate of maturing and size at maturity were found between females of the two types. The two sexes showed also differences in rate of maturity and size.

Heritabilities and genetic correlations were estimated using animal model procedures where all information came from mother-offspring relationships. Heritability estimates were 0.36, 0.27, 0.15, 0.09, and 0.11 for BW, HW, CC, BL, AC, genetic correlations varied between 0.55 and 0.94.

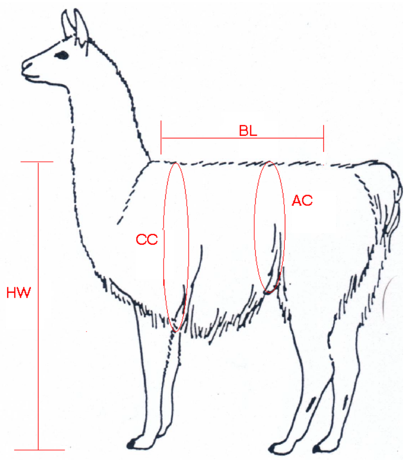
Introduction

Llama husbandry plays an important role in the High Andes of Bolivia, because of the extreme environment that limits the cultivation of any kind of crop plants. Most products of llamas are used within the local community, but are also source of some cash income from selling fibre and meat. The University of Hohenheim, Germany, works together with the local NGO ASAR (Asociación de Servicios Artesanales y Rurales) and the Universidad Mayor de San Simón, Cochabamba, Bolivia and the University of Agricultural Sciences, Vienna, Austria, on a project with the aim of providing a comprehensive description of the system of llama keeping and investigating possible pathways for improvement. Within the scope of the project the production system and the national and international market for wool are investigated (Delgado et al. 1999, Nürnberg and Valle Zárate 2000).

Genetic selection is one way of improvement. Changes in performance achieved by selection are usually small but in contrast to other kinds of improvement they are permanent and cumulative. To evaluate the opportunities for genetic selection, phenotypic and genetic parameters for the traits of interest have to be estimated. Results presented here concentrate on such parameters for growth traits.

Material and Methods

The study was carried out in 4 indigenous communities of the eastern slope of the Andes in Bolivia, in the Province of Ayopaya, Department Cochabamba. Communities are located on different altitudes. Community 1 and 4 are located at 4300 m, community 2 at 4100 m and community 3 at 3800 m above sea level respectively. The direct distance between the communities varies between 3 and 10 km.



Data were recorded from 1998 to 2001. A total number of 3894 sets of five body measurements were taken from 2821 llamas and 1576 weights were collected from 1536 llamas. Height at withers (HW) was measured from the highest point of the processus spinalis of the vertebra thoracica to the floor, chest circumference (CC) was taken behind the forelegs, body length (BL) from the highest point of the processus spinalis of the vertebra thoracica to the os sacrum and abdomen circumference (AC) was taken in front of the hind legs. All measurements were taken with a tape. Body weight (BW) was measured with an electronic balance.
Two different types of llamas were distinguished. „Th`ampullis" (T-type) are regarded as „wool-llamas" with notably higher fleece yields, Kh`aras (K-type) are meat-oriented llamas with reduced fleece growth. The age of the animals was identified by denting.
The age structure and distribution of the two different types are shown in Table 1.

Table 1. Age structure and distribution of types (number of body measurements)

Age (years)	<1	1	2	3	4	5	6	7	8	>8
Th`ampulli males	195	241	198	71	30	11	14	6	2	1
Kh`ara males	9	17	12	10	1	1	1	0	0	0
Th`ampulli females	165	255	314	342	305	339	329	229	180	110
Kh`ara females	32	25	32	32	42	51	51	30	22	13

The growth curve was described with the non-linear Brody function (Fitzhugh 1976):

$$y(t) = a*(1-b*e^{-k*t})$$

where y(t) is size or weight at given time t, a is a curve parameter that predicts asymptotic size or weight at maturity, b is the proportional difference between a and birth size or weight and k is a curve parameter that shows the rate of maturing. The analysis of growth curves was carried out using procedure NLIN of SAS (SAS Institute Inc., 1988). As the number of Kh`ara males was small, they were excluded from analysis. Male castrates were also excluded for the estimation of growth curves but not for the estimation of genetic parameters as described below. Statistical significance tests were performed for the comparison of the two sexes using Th`ampulli data and for Th`ampulli versus Kh`ara using data from female animals. For estimation of differences between environmental conditions in the communities only data from Th`ampulli females were used.
The estimation of genetic parameters relied exclusively on mother-offspring relationships. A total of 860 mother-offspring pairs were found in the data set. The following statistical model was used for estimation of heritabilities and genetic correlations:

$$Y_{ijklmno} = \mu_i + F_{ij} + T_{ik} + S_{il} + YS_{im} + b_{1i}x + b_{2i}x^2 + a_{in} + pe_{io} + e_{ijklmno}$$

Y_{ijklmn} = observed value for traits i, i=1,5 (BW, HW, BL, CC and AC)
μ_i = constant common to all individuals for trait i
F_{ij}= fixed effect of farmer j, j = 1,65; T_{ik} = fixed effect of type k, k = 1,2 (Th`ampulli, Kh`ara);
S_{il} = fixed effect of sex l, l = 1,3 (male, female, male castrated); YS_{im} = fixed effect of year-season m, m = 1,3 (Nov. 1998, Oct. 1999 to Feb. 2000, Oct. 2000 to Jan. 2001);
b_{i1}, b_{i2} = linear and quadratic regression coefficients

x =age in years (to avoid the bad fit of a quadratic regression for “old” adult animals, ages > 5 were set to 5); a_{in} = random additive genetic animal effect n=1, 2794; pe_{io}= random permanent environmental effects, o=1,2794; $e_{ijklmno}$ = random residual effect.
The estimation of genetic parameters was carried out with the VCE program (Groeneveld, 1998).

Results and discussion

The distribution of the 2 types Khara and Th’ampulli across ages is shown in table 1. In contrast to other departments of Bolivia more Th´ampullis than Kh´aras are found in our study area. In the departments La Paz, Oruro, Potosí of the Altiplano the proportion of Kh´ara varies between 65 and 83 %, whereas in the department of Cochabamba only 53% of the llamas are classified as Kh´ara (FIDA, FDC, UNEPCA, CAF, 1999). Súmar (1991) reports from the Peruvian Altiplano a population structure of 80% Kh´ara type and 20% Th´ampulli type.
Table 2 presents the results of the growth curve estimation. Significancies for the a value (level at maturity) between the two types were found for HW and CC. The b and k values of the AC for the T-females were significantly higher than those for the K-females.
The a value for HW and BW of the T-males was significantly higher than for T-females. Differences for the b value were found for HW and BL. The k values of the curve for HW, CC and BW of the T-females were significantly bigger than those for the T-males. That means that females are early maturing.

Table 2. Estimates (± standard deviations) of the parameters of the Brody growth curve for different traits.

		Th`ampulli (T)		Kh`ara (K)	Significance level	
Traits	*	males	females	females	sexes	types
		n = 769	n = 2568	n = 330		
HW,	a	106.4 ± 1.15	101.9 ± 0.17	103.5 ± 0.45	sig	sig
(cm)	b	0.398 ± 0.01	0.368 ± 0.01	0.373 ± 0.01	sig	n.s.
	k	0.581 ± 0.58	0.771 ± 0.02	0.763 ± 0.05	sig	n.s.
CC,	a	113.3 ± 1.37	111.3 ± 0.23	113.2 ± 0.54	n.s.	sig
(cm)	b	0.519 ± 0.01	0.511 ± 0.01	0.511 ± 0.01	n.s.	n.s.
	k	0.655 ± 0.04	0.763 ± 0.02	0.756 ± 0.04	sig	n.s.
BL,	a	78.1 ± 1.04	78.4 ± 0.28	78.5 ± 0.70	n.s.	n.s.
(cm)	b	0.551 ± 0.01	0.512 ± 0 14	0.539 ± 0.03	sig	n.s.
	k	0.817 ± 0.06	0.755 ± 0.03	0.841 ± 0.09	n.s.	n.s.
AC,	a	83.0 ± 1.41	83.6 ± 0.26	83.2 ± 0.72	n.s.	n.s.
(cm)	b	0.537 ± 0.02	0.559 ± 0.01	0.503 ± 0.02	n.s.	sig
	k	0.796 ± 0.07	0.886 ± 0.03	0.709 ± 0.07	n.s.	sig
		n = 293	n = 980	n = 120		
BW,	a	101.1 ± 7.02	75.3 ± 0.62	74.3 ± 1.54	sig	n.s.
(kg)	b	0.851 ± 0.02	0.910 ± 0.03	0.934 ± 0.11	n.s.	n.s.
	k	0.258 ± 0.04	0.530 ± 0.0	0.614 ± 0.10	sig	n.s.

n = number of observation, n.s. = non significant, sig = significant, $p<0.05$; for definition of growth parameters a, b and k and definition of traits see text overleaf

In Figure 1 the growth curves for height at withers of T-type males and T-type females are described. Figure 2 shows the differences between the T-type females and the K-type females regarding the same trait.

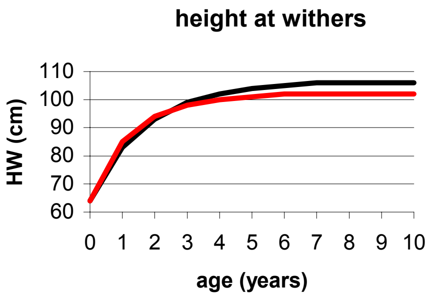


Figure 1. Comparison of the growth curves for HW between T-males (black line) and T-females (red line)

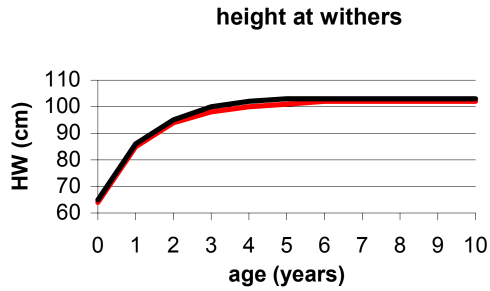


Figure 2. Comparison of the growth curves for HW between T-females (red line) and K-females (black line)

The development of body weight in the two sexes and the two types are compared in Figures 3 and 4.

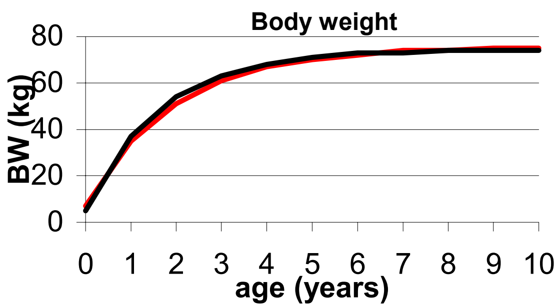


Figure 3. Comparison of the growth curves for BW between T-males (black line) and T-females (red line)

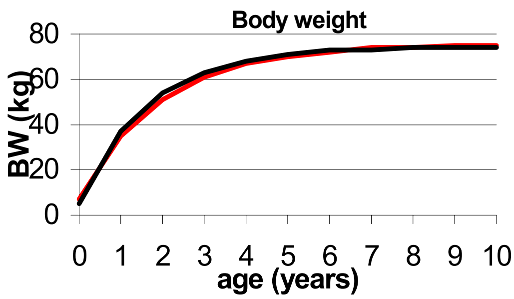


Figure 4. Comparison of the growth curves for BW between K-females (black line) and T-females (red line)

In the present study the Kh`ara type was taller with respect to HW. Cardozo and Choque (1987) found that the K-type with 99 cm was taller than the T-type with 95 cm. The results from Vidal (1967) also indicate that the K-type is taller than the T-ype. In contrast to these results Parra (1999) and Súmar (1991) gave the same height for both types. In the studies of Cardozo and Choque (1987) and Vidal (1967) the results show that males of both types reach a higher value of HW. All literature mentioned above showed data from llamas raised in South America. In contrast to these the results of Spira (1995) indicate that llamas raised in Europe are taller. Males were up to 130 cm and females up to 120 cm at withers.

In our study the a value for CC varied from 111 cm to 115 cm. Parra (1999) observed 99 cm and Cardozo and Choque (1987) presented values between 101 cm and 112 cm.

It is difficult to compare the results of the body length because of different definitions of the trait. In this study the results were between 78 cm and 84 cm, whereas Cardozo and Choque (1987) gave values between 95 cm and 101 cm. Maquera (1991) reports values for one year old animals of the T-type of 63 cm and for K-types of 65 cm. In our study the BL for both types at one year was 60

cm and the results for AC were between 80 cm and 83 cm. Cardozo and Choque (1987) presented higher measurements between 95 cm and 103 cm.
The mature weight for T-males was 101 kg and for T-females 75 kg. Cardozo and Choque (1987) found higher values for males than for females for both types. Paca (1977) presented higher body weights for Peruvian llamas. Males reached 152 kg with 5 years and females 150 kg at the same age. According to Bustinza and Sucapuca (1987) Peruvian llamas with 8 years weighed between 70 and 93 kg. In our study birth weight varied from 5 to 15 kg. These results are in the line with Bustinza and Sucapuca (1987) and Chávez (1991). Spira (1995) again gave much higher values for both sexes. Females weighed between 80 and 120 kg and males from 90 up to more than 200 kg. This may be due to better feeding conditions and selection of breeding animals for export to Europe.

Table 3. Estimates (± standard deviations) of the parameters of the Brody growth curve for different traits in Th´ampulli females in 4 communities

Traits	*	Community 1	Community 2	Community 3	Community 4
		n = 469	n = 1409	n = 121	n = 569
HW, (cm)	a	101.2 ± 0.40	102.0 ± 0.23	103.6 ± 0.96	101.9 ± 0.37
	b	0.396 ± 0.03	0.361 ± 0.01	0.373 ± 0.02	0.373 ± 0.01
	k	0.860 ± 0.07	0.749 ± 0.03	0.687 ± 0.09	0.784 ± 0.04
CC, (cm)	a	111.6 ± 0.59	111.3 ± 0.31	110.6 ± 1.09	110.7 ± 0.51
	b	0.543 ± 0.03	0.507 ± 0.01	0.503 ± 0.03	0.510 ± 0.01
	k	0.775±0.05	0.758±0.03	0.797±0.09	0.786±0.04
BL, (cm)	a	^{a}79.6 ± 0.63	^{a}79.8 ± 0.35	^{b}72.6 ± 1.17	^{b}74.8 ± 0.58
	b	0.572 ± 0.05	0.504 ± 0.02	0.531 ± 0.05	0.515 ± 0.02
	k	0.874 ± 0.11	0.749 ± 0.04	0.814 ± 0.15	0.753 ± 0.06
AC, (cm)	a	82.9 ± 0.61	84.2 ± 0.34	82.7 ± 1.00	82.8 ± 0.57
	b	0.606 ± 0.05	0.553 ± 0.02	0.633 ± 0.06	0.556 ± 0.02
	k	0.937 ± 0.09	0.858 ± 0.04	1.452 ± 0.23	0.898 ± 0.07
		n = 110	n = 627	n = 0	n = 243
BW, (kg)	a	73.8 ± 1.76	75.7 ± 0.70		73.6 ± 1.39
	b	0.954 ± 0.09	0.919 ± 0.03		0.942 ± 0.06
	k	0.597 ± 0.09	0.557 ± 0.03		0.509 ± 0.05

n = number of observation, for definition of growth parameters a, b and k and definition of traits see text
a, b differences in superscripts indicate significant ($p<0.05$) differences between communities

Nürnberg and Valle Zárate (1999) noticed that there is very little exchange of breeding animals between herds within a community and between communities. A diversification within the population could be expected. However, for none of the observed traits in table 3 significant differences were found between communities, exept for the a-value of body length. The llama population studied so far proved to be very uniform. The differences in the environmental conditions within the study region seem to have had low influence on the growth of the animals.

Table 4. Estimates of heritabilities and σ^2_{pe}/σ^2_y (diagonal), genetic correlations (above diagonal) and correlations between permanent environmental effects (below diagonal)

	BW	HW	CC	BL	AC
BW	*0.36/0.35*	0.66	0.83	0.87	0.82
HW	0.63	*0.27/0.09*	0.81	0.77	0.65
CC	0.64	0.99	*0.15/0.21*	0.63	0.94
BL	0.62	0.99	0.99	*0.09/0.15*	0.55
AC	0.65	0.77	0.75	0.86	*0.11/0.03*

The heritabilities for BW, HW, CC, BL and AC (Table 4) were estimated as 0.36, 0.27, 0.15, 0.09 and 0.11. Heritabilities were lower for the body measurement than for body weight. One explanation for this difference could be measurement errors caused by the effect that most llamas were not sheared. In the multivariate estimation it was not possible to determine standard errors but univariate estimation yielded similar heritabilities and the standard error for weight was 0.08 and for the other body measurements between 0.02 and 0.04. The genetic correlations varied between 0.55 and 0.94. Choque (1988) estimated the heritability of birth weight as 0.47 and for weaning weight 0.35. These estimates were based on only 56 observations.
The proportion of the permanent environmental variance was highest for BW (0.35). The correlations between permanent environmental effects were between 0.62 and 0.99.

Conclusion

The growth traits of the llama population of Ayopaya are in the range of results given in the literature for other populations in South America. Compared to data from Europe the llamas are smaller and lighter.
Differences regarding body measurements between the two types are small and therefore classification only based on these measurements seems difficult. This conclusion is in contrast to Cardozo and Choque (1987), who suggested HW and BW as a suitable instrument for classification, whereas in most studies the two types are distinguished by different fleece characteristics (e.g. Súmar 1991).
No reliable values for the heritabilities of the different growth traits were available from literature. The values in this study are similar to heritabilities estimated for other species and indicate chances for change by genetic selection. Whether growth traits should actually be changed depends on a large number of factors related to the system of production.

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