Genetic Evaluation Of Fiber Characteristics In Huacaya Alpaca In The U.S.A.

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Introduction

Alpaca from South America were first imported into the U.S.A. in the 1980's (AOBA, 2010), mainly from small herds located in Quechua and Aymara villages in Chile. These initial importations were followed by a series of larger importations in the 1990's, initially from Bolivia and subsequently from Peru (Safley, 2004). Animals for these later importations were largely derived from Peruvian breeding cooperatives. The population in the U.S.A. was closed to further imports in 1998, and registrations of alpaca in North America surpassed 194,000 animals in 2010 (ARI, 2010).

A program for genetic evaluation of fiber characteristics in Huacaya alpaca in the U.S.A. was initiated in 2004 by the Ideal Alpaca Community (IAC, 2010). Estimated breeding values were first released for Huacaya alpaca in 2008 and extended to Suri alpaca in 2010. Objectives of this study were to determine effects of animal age, sex and color on fleece weight and fiber characteristics and to estimate genetic parameters for these traits in Huacaya alpaca.

Material and methods

Records of fleece weights (FWT; kg) and fiber quality characteristics were obtained for 4,070 Huacaya fleeces produced by 3,111 animals from 108 farms from across the U.S.A. and representing a total of 713 sires and 1,188 dams. Of these, 50 sires had 5 or more progeny with records. Fiber measurements included the staple length (SL; mm), mean (FD; microns), SD (microns), and CV (%) of fiber diameter across the staple, mean curvature (CUR; degrees), and percentage of medullated fibers (MED; determined only for white, light fawn, and light beige fleeces) and were assessed at the Yocom-McColl Testing Laboratories (Denver, Colorado) using International Wool Textile Organization methods and equipment (Lupton et al., 2006). Effects of animal age at shearing, sex, and color were determined using a model that included these effects as well as those of farm and shearing date. Measurements were subsequently adjusted to a shearing age of 12 mo and (co)variance components were estimated with MTDFREML software (Boldman et al., 1993) using a model that included fixed effects of farm, shearing date, and sex and random residual and animal additive and permanent environmental effects in bivariate analyses for all pairs of measurements. The final pedigree file contained 4,663 animals that, in most cases, traced to imported foundation males. Estimated breeding values were then derived for all animals in a 5-trait multivariate analysis of FWT, FD, SD, CUR, and MED.

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Results

Sex effects were not significant for SL, FD, SD, CUR, or MED. Mean fleece weights in females increased from 2.2 kg at 1 yr to 2.8 kg at 2 yr and then declined, with means of 2.5 kg at 4 yr of age and 2.2 kg in animals greater than 6 yr of age. However, in males mean fleece weights increased from 2.2 kg at 1 yr of age to 3.2 kg at 2 yr and 3.8 kg at 3 yr before gradually declining to3.2 kg in animals older than 6 yr of age. Staple length was highest at 1 yr of age in both sexes (average of 112 mm) and subsequently declined to average values of 90 mm at 4 yr of age and 74.2 microns in animals over 6 yr of age. Fiber diameter increased asymptotically with age, from an average of 21.1 microns at 1 yr to 26.0 microns at 4 yr and to 27.8 microns in the oldest animals. The SD of fiber diameter likewise increased asymptotically with age, from 4.6 microns at 1 yr to 5.2 microns at 4 yr and to 5.9 microns in the oldest animals. In contrast, CV declined asymptotically in females from 22.0% at 12 months to 20.3% in animal older than 4 yr of age and in males from 22.2% at 1 yr to 20.4% at 4 yr and then to 19.0% in the oldest animals. The mean curvature was 36.5 degrees at 1 yr of age and declined linearly and uniformly with age in both sexes at a rate of -.046 degrees/month. The percent medullated fibers increased asymptotically with age and the pattern of increase differed between sexes. In females, the percentage of medullated fibers increased from 12.3% at 1 yr to 25.0% at 4 yr and 33.2% in the oldest animals; in males, the percentage of medullated fibers was similar to that of females at 1 yr of age (12.5%) but subsequently increased more rapidly, to 28.1% at 4 yr and 37.4% in the oldest animals.

Associations between fleece color and quality attributes were derived only for the more numerous female records. Clear gradients of increasing fiber diameter and SD and declining fleece weight and curvature were observed as fleece color darkened (Table 1). Color effects on staple length were also detected by F test ($P < 0.05$), but specific differences among color groups in SL could not be detected using the Studentized Range test (Snedecor and Cochran, 1967). Color effects on CV were not consistent, involving only a high level of relative variability for bay-black individuals. Color effects on incidence of medullated fibers could be assessed only for the six lightest fleece colors and were not significant. The decision of whether color differences are of environmental origin (i.e., if darker fibers are coarser and have less crimp independent of genetic background) or reflect genetic differences (i.e., greater selection history for fineness in white and light-colored animals) is an important one in genetic evaluation. If darker fleeces are necessarily coarser, then color effects should be removed before assessing underlying genetic merit but should then be reconsidered by predicting anticipated color outcomes of specific matings. If color effects reflect different selection histories and are not innate to the darker fibers, then corrections for color effects should not be included in the genetic analysis. These data did not provide definitive guidance on the proper choice; we chose to exclude color effects from the genetic prediction models.

Estimates of genetic parameters for fiber characteristics are shown in Table 2. Heritability estimates were similar to those reported for fine-wool sheep (Safari et al., 2005) and other fiber-producing species and were less than 0.41 only for CV of fiber diameter. Heritability estimates from Peruvian alpaca were similar to ours for FD and CV, but lower for FWT and SL (Gutiérrez et al., 2008). Genetic correlations of fleece weight with other variables did not, however, conform to expectations, with nonsignificant, but generally favorable, genetic associations of fleece weight with the mean and SD for fiber diameter, curvature, and incidence of medullated fibers. However, phenotypic correlation of fleece weight with fiber diameter, curvature, and incidence of medullated fibers revealed modest antagonistic relationships, reflecting larger and more clearly antagonistic residual and animal permanent environmental correlations. Genetic correlations involving traits other than fleece weight were generally consistent in sign and reasonably consistent in magnitude with those expected from results in other fiber producing species and from studies of alpaca in Peru (Gutiérrez et al., 2008; Morante et al., 2009).

Table 1: Associations of fleece color with fiber traits in female Huacaya alpaca. Effects are expressed as deviations from means for white animals.

Color	No.	FWT	FD	SD	CV	CUR	SL
Black	185	-0.44[a]	2.53[a]	0.56[a]	0.29[a]	-9.12[a]	1.71
Bay Black	57	-0.25[ab]	1.15[b]	0.69[a]	2.06[b]	-6.88[ab]	0.82
Dark Brown	86	-0.27[ab]	1.56[b]	0.30[ab]	0.24[a]	-4.70[bc]	-3.81
Medium Brown	242	-0.32[ab]	1.45[b]	0.24[b]	-0.04[a]	-3.29[cd]	-3.65
Light Brown	80	-0.36[ab]	1.61[b]	0.20[b]	-0.32[a]	-2.56[cd]	-5.73
Dark Fawn	69	-0.38[ab]	0.77[b]	0.18[b]	0.28[a]	-1.94[cde]	-3.92
Medium Fawn	409	-0.33[ab]	0.52[b]	0.07[b]	0.22[a]	0.20[de]	-5.24
Light Fawn	278	-0.23[ab]	0.57[b]	0.03[b]	-0.17[a]	-0.33[cde]	-2.13
Beige	91	-0.14[b]	-0.17[c]	0.03[b]	0.37[a]	0.71[de]	-2.30
White	1,282	0.00[b]	0.00[c]	0.00[b]	0.00[a]	0.00[de]	0.00

[abcde] Values within a column with different superscripts differ ($P < 0.05$) using the Studentized Range test (Snedecor and Cochran, 1967).

Table 2. Estimates of heritability (diagonal; bold), genetic correlations (above the diagonal), phenotypic correlations (below the diagonal), phenotypic variance (σ_P^2) and repeatability (t) across years for fleece weight (FWT; kg), staple length (SL; mm), mean fiber diameter (FD; microns), standard deviation in fiber diameter (SD; microns), CV of fiber diameter (%), mean curvature (CUR; degrees) and percent medullated fiber (MED) in Huacaya alpaca in the U.S.A.

Item	FWT	SL	FD	SD	CV	CUR	MED
FWT	0.42	0.33	-0.13	-0.12	-0.01	0.07	-0.05
SL	0.29	0.41	0.24	0.26	0.05	-0.58	0.29
FD	0.16	0.23	0.49	0.61	-0.11	-0.76	0.46
SD	0.03	0.14	0.55	0.48	0.65	-0.48	0.52
CV	-0.11	0.04	-0.15	0.58	0.24	0.05	0.09
CUR	-0.09	-0.02	-0.64	-0.36	0.10	0.48	-0.67
MED	0.10	0.19	0.60	0.46	0.02	-0.48	0.56
σ_P^2	0.48	249.7	7.26	0.68	10.0	52.4	91.1
t	0.63	0.59	0.74	0.71	0.65	0.83	0.83
No. records	1,703	1,640	4,068	3,617	3,617	2,229	1,214
No. animals	1,291	1,243	3,109	2,681	2,681	1,560	883
No. sires	593	578	711	711	711	673	364
Mean	2.83	113.6	21.1	4.64	20.4	33.3	12.3

Given the relatively recent establishment of the alpaca population in the U.S.A., we hypothesize that the approximate independence of fleece weight and fiber diameter at the genetic level is a result of residual linkage disequilibrium associated with nonrandom sampling of founder animals from the South American population(s). A subset of mainly white imported animals was chosen from elite flocks with a substantial history of selection for both fleece weight and fiber diameter. However, additional imported founders were also chosen to acquire genetic diversity, and particularly to ensure that the full range of colors was represented in the importations.

Highly selected animals chosen from elite flocks predominantly had the white fleeces that are favored by the international fiber market and were likely superior in most fiber characteristics (including both fleece weight and fiber diameter) to colored animals chosen, at least in part, to ensure genetic diversity in color alleles among imported animals. Such a pattern of selection would potentially give rise to linkage disequilibrium that could account for the unanticipated genetic relationships between fleece weight and other fiber characteristics, especially if reinforced by differential selection goals among breeders in the U.S.A. Somewhat surprisingly, restriction of the data to only white animals did not affect the pattern of genetic correlations, perhaps in part reflecting effects of intervening segregation of the original color alleles in the USA population.

Estimated breeding values and other reports associated with the genetic evaluation of alpaca in the U.S.A. can be found at http://ideal-alpaca.com.

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