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Fibre Characteristics of Huacaya Alpaca in Peru

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ABSTRACT

Background: The fibre characteristics of fleece weight (FW), mean fibre diameter (MFD), coefficient of variation of mean fibre diameter (CVMFD) and common phenotypic correlations between them of Huacaya alpacas (*Vicugna pacos*) breed, were estimated on 959 one-year-old animals, under extensive rangeland management conditions.

Methods: Samples were taken between 2005 and 2018 (male and female), of two coat colors (white and brown), at the Toccra CEDAT-DESCO Alpaca Development Center (Arequipa, Perú). Model were developed an they included year, sex and coat color and their interactions with FW, MDF and CVMDF of alpaca's fibre under the experimental design was completely randomized with a factorial arrangement of 12×2×2.

Result: Statistical significant effect was for year of birth × sex interaction when FW was analyzed while year of birth × color interaction explained MFD and CVMFD variation ($p<.001$). Phenotypic correlation calculated by Pearson's coefficient showed that FW was positively correlated with MFD (0.24) while CVMFD was positively correlated with MFD (0.10). Results from this study indicated that the FW was influenced by both year of birth and sex, while MFD and CVMFD were influenced by both year of birth and color. Overall, it was concluded that a genetic progress can be achieved in the huacaya alpaca breed of CEDAT genetic improvement program.

Key words: Alpaca, Correlation, Fibre diameter, Fleece weight.

INTRODUCTION

Alpaca production is the main activity carried out by the high Andean smallholders in South American (Quispe *et al.,* 2009). Peru occupies the first place in the world alpaca population with 3,592,482 heads (INEI, 2012). Alpaca genetic improvement is a way to raise herd productivity and to contribute to poverty reduction and food insecurity in these communities relying on alpaca production (Quispe *et al.,* 2013).

The textile industry considers alpaca fibre as a special fibre. The garments made from this fibre are classified as fashion clothes by international markets. The fleece weight and fibre diameter are the principal characteristics that should be considered as selection criteria within a genetic improvement program (León-Velarde and Guerrero, 2001; Quispe, 2010). The quality evaluation of alpaca fiber could be carried out in tuis alpacas (one year old) because it is influenced by age, color of the fleece and place of origin, whereas sex and body area of the sample collection have lesser influence (Machaca *et al.,* 2017). Actually, 22 natural alpaca fleece colors have been established: from white to black with many shades of beige and brown and different color schemes (Renieri *et al*. 2004, Oria *et al*. 2009). However, around two-thirds of the alpaca's population are of white fiber (INEI, 2012). The fibre obtained from the 1-year old alpaca animals is eligible for a so-called thinnest "Royal alpaca" and according to Peruvian standards should not exceed more than 19.5 microns (Morante *et al.,* 2009), but there exists still finer fiber, like the new commercial category called "alpaca sixteen" referring to mean fiber diameter below 17 μm. In addition, for an optimal quality, the fiber diameter must be accompanied by uniformity and this is assessed by low values of standard deviation (Cruz *et al*. 2020).

The current alpaca's population has a great potential for genetic improvement, so there is the possibility of producing fine alpaca fibre that meets the demands of the textile industry. The fiber diameter, fleece weight, comfort factor and fineness of spinning are the main characteristics

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from commercial and manufacturing points of view (Quispe *et al.,* 2009).

However, the lack of uniformity in fleece weight and diameter along its length has an impact on fiber quality (Wuliji *et al.,* 2000; Quispe *et al.,* 2008). However, as aforementioned the improvement through breeding might be an alternative to increase the quality of the fibre. The objectives of the present study were to evaluate the fibre characteristic and their degree of association in 1 year old Alpaca animals from Peru. This paper will contribute to a better understanding of the main drivers that will contribute in explaining genetic improvement in Alpaca herds.

MATERIALS AND METHODS

Animals and management

Mid-side samples (n = 959, ca. 10 g) from Huacaya alpaca (*Vicugna pacos*) breed were provided by the Toccra Alpaca Development Center (CEDAT). The samples were taken between 2005 and 2018 from 1-year-old animals (male and female), of two coat colors (white and brown; Table 1). Animals were fed in natural pastures and the predominant plant were *Poaceae, Cyperaceae, Asteraceae* and *Juncaceae* families.

Study of area

The CEDAT is located at 4400 masl, in the annex of Toccra, Yanque district, Caylloma province, Arequipa department (15°39¼01" S; 71°35¼01" W. The climatic characteristics correspond to dry puna ecoregion, with temperatures ranging between -20°C and 15°C and rainfall 350 mm/year.

Recording and measurements

The alpacas were first shorn at 12 months of age, fleeces were weighed and a mid-side sample was taken for analysis. Fleece weights were determined for each alpaca at shearing time by subtracting the greasy fleece weight from the liveweight recorded immediately before shearing. Each sample prior to microscopic examination was washed in warm water with detergent and rinsed several times. After natural drying the fibers were cut with scissors in order to prepare the samples for microscopic measurements. Samples were analyzed at the Textile Fibre Laboratory of the Camerino University, Camerino, Italy, using OFDA (OFDA-2000, Interactive Wool Group (IWG) Pty, Australia). The fleece characteristics analyzed were fleece weight (FW), mean fibre diameter (MFD) and coefficient of variation of mean fibre diameter (CVMFD).

Statistical analysis

The experimental design was completely randomized with a factorial arrangement of 12×2×2 by using 959 alpacas. The model included year, sex and coat color and their interactions on FW, MFD and CVMFD. The analyses were performed by using the MIXED and CORR procedures of SAS (SAS Institute Inc., 2011). The averages were fit by minimum squares to compare with the least significant difference (LSD) test ($P = 0.05$). The applied statistical model can be described as follows:

$$\gamma_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \alpha\gamma_{ik} + \beta\gamma_{ik} + \alpha\beta\gamma_{ijk} + \varepsilon_{ijkl}$$

Where

γ_{ijkl} is the response variable in animal l, coat color k, sex j and year of birth i; μ is general mean; α_i is the effect of the ith year of birth; β_j is the effect of the jth sex; γ_k is the effect of the kth coat color; $\alpha\beta_{ij}$ is the effect of the interaction year of birth-sex; $\alpha\gamma_{ik}$ is the effect of the interaction year of birth-coat color; $\beta\gamma_{ik}$ is the effect of the interaction sex-coat color; $\alpha\beta\gamma_{ijk}$ is the effect of the interaction year of birth-sex-coat color; ε_{ijkl} is the random error associated with the lth animal, kth coat color, jth sex and ith year of birth.

RESULTS AND DISCUSSION

Sample characteristics

Descriptive statistics for the fibre trait are reported in Table 1. The Tuis alpacas analyzed in this study have lower FW (1.54 kg) compared with similar studies reported by other authors using adult animals (2.16 kg, Wuliji *et al.,* 2000). It is important to note that this study did not directly compare the results of young animals with those in adult alpaca animals. However, the results obtained in this study might be associated with the different physiology and nutrient expected between young and adult alpaca animals. In particular, this can be true in relation to body growth and less available nutrients for fiber production compared with adult animals (National Research Council, 2007). Similarly, to FW, MFD showed a similar trend. This parameter showed low values if they are compared with those reported by other authors using adult animals (28 µm, Wuliji *et al.,* 2000) and according to the last classification of fibers is within the “Royal Alpaca” category (Morante *et al.,* 2009). Overall, all the alpaca fibre traits evaluated showed a wide range in composition with coefficient of variation (CV) higher than 9% (Table 1), where the widest range was observed for FW and CVMFD.

Table 1: Statistical parameters for the variables measured in alpaca fibre samples.

Trait	N	Mean	S.D.	Minimum	Maximum	CV
FW (kg)	873	1.54	0.36	0.55	3.00	23.10
MFD (µm)	959	19.50	1.85	14.70	26.95	9.47
CVMFD (%)	957	21.25	3.49	9.85	37.72	16.42

S.D. = Standard deviation; CV = Coefficient of variation (%) = (s.d./mean) ×100; FW = Fleece weight; MFD = Mean fibre diameter; CVMFD = Coefficient of variation of mean fibre diameter.

Fixed effects on fibre traits

Table 2 shows the analysis of variance (ANOVA) for the fixed effects on fibre traits. Statistically significant effects were observed for FW, MFD and CVMFD at the level of second-order interactions for the factors of year of birth, sex and color ($P < 0.01$).

The interaction between year of birth × sex was statistically significant for FW ($P < 0.01$), indicating that the effect of year of birth on FW was different for each sex of the animals (Table 3). The female animals had higher FW than the male animals harvested in 2012 and 2013 (2.0 vs. 1.8 kg and 1.6 vs 1.4 kg, respectively). However, for animals harvested in 2015, the FW was higher in the male animals (1.7 vs 1.2 kg; Table 3). This might be explained by the fact that male animals tend to be heavier than female animals, thus providing more surface area of their skin for production of wool fibre. This is in agreement with results reported by other authors (Gupta *et al.,* 2015). Tomar *et al*. (2000), reported similar findings for the effect of sex of animals in Merino sheep. For all other years, FW was similar ($P < 0.05$) between males and females. The results from this study are similar to those reported by Wuliji *et al*. (2000) in alpacas and Ahmad *et al*. (2010) and Gupta *et al*. (2015) in sheep. The apparent annual average variation in the FW was 30% per year, however, when FW was compared as function of sex, the variation was 26%. Differences in FW in different year of birth could be attributed to the dietary differences related to environmental factors (*e.g.*, rainfall variation) affecting availability of pastures over the year. McGregor (2002) found in alpacas Huacaya a similar reduction of fiber performance by poor nutrition, with a loss of 0.95 kg of FW. Similar results were also reported in earlier studies in sheep by other authors (Kumar *et al.,* 2006; Gupta *et al.,* 2015). McGregor and Howse (2018), reported that in Angora goats from Australia the first FW is affected by birth parity and sex of progeny, but not by subsequent fleeces. Genetic differences among years of birth may also be present in this population (Gowane *et al.,* 2016).

A statistically significant effect was observed for the year of birth × color interaction ($P<0.01$) for both MFD and CVMFD (Table 4). The alpacas born in 2018 had the lowest fibre diameter, while both white and brown alpacas had similar fibre diameter (18.0 and 18.2 µm, respectively). The highest fibre diameter was observed in white and brown alpacas born in 2005, 2007 and 2012. Nevertheless, lower values were observed between 2013 and 2018. These results might indicate the efficiency of the breeding program implemented by the CEDAT-DESCO Alpaca Development Center (Harizi and Abidi, 2015). Cruz *et al*. (2017) indicated that the relevant factors that influence fibre performance are year, color and age of animal. These authors reported that dark coat animals were 3.09 µm coarser than white ones in Huacaya breed and 5.93 µm more than in Suri. Montes *et al*. (2013) reported values of 21.65 ± 0.36µm for tuis alpacas of 1.5-year- old. However, in the samples measured from the middle of an animal's side, some studies have reported higher average

Table 2: Analysis of variance for fixed effects on fibre traits in alpacas.

Source of variation	Means square error		
	FW	MFD	CVMDF
Year of birth	0.997**	42.620**	269.267**
Sex	0.158^{ns}	2.941^{ns}	12.922^{ns}
Year of birth × Sex	0.263**	2.924^{ns}	6.152^{ns}
Color	0.119^{ns}	0.027^{ns}	45.633^{ns}
Year of birth × color	0.211^{ns}	7.239**	26.751**
Sex × color	0.009^{ns}	1.207^{ns}	36.014^{ns}
Year of birth × sex × color	0.198^{ns}	4.724^{ns}	8.116^{ns}
Residual error	0.107	2.644	8.599

Statistical significance at: ** ($P \leq 0.01$); ns = non-significant; FW = Fleece weight; MFD = Mean fiber diameter; CVDF= Coefficient of variation of mean fibre diameter.

Table 3: Mean square for fleece weight (kg) to year of birth and sex interaction.

Year of birth	Sex	
	Males	Females
2005	1.5±0.3^{CDa}	1.4±0.4^{CEa}
2006	1.4±0.3^{Da}	1.4±0.2^{CEa}
2007	1.6±0.3^{BCa}	1.5±0.3^{CEa}
2009	1.4±0.2^{BDa}	1.4±0.3^{CEa}
2011	1.9±0.4^{Aa}	1.6±0.3^{BCDa}
2012	1.8±0.5^{Ab}	2.0±0.5^{Aa}
2013	1.4±0.3^{CDb}	1.6±0.3^{Ba}
2014	1.5±0.3^{BDa}	1.5±0.3^{BEa}
2015	1.7±0.3^{ABa}	1.2±0.3^{Eb}
2016	1.5±0.3^{CDa}	1.4±0.4^{DEa}
2017	1.6±0.3^{ABDa}	1.6±0.3^{BCa}
2018	1.4±0.3^{CDa}	1.4±0.3^{DEa}

Table 4: Mean square for fibre diameter (µm) and Coefficient of variation of fibre diameter (%) to year of birth and color interaction.

Year of birth	MFD		CVMFD	
	Color		Color	
	White	Brown	White	Brown
2005	20.2±1.8^{Ba}	19.3±1.7^{CDb}	19.8±4.3^{Fa}	18.7±4.1^{Ea}
2006	19.0±1.6^{Ea}	18.9±1.5^{CDa}	18.4±3.9^{Ga}	16.3±2.9^{Fb}
2007	21.0±1.6^{Aa}	21.2±1.7^{Aa}	23.2±2.9^{Aa}	24.0±3.3^{ABa}
2009	19.1±1.3^{CEFa}	20.1±1.8^{ABCa}	22.6±1.9^{ACa}	21.8±1.7^{BDa}
2011	19.2±1.2^{CEa}	19.1±1.9^{BDa}	22.1±2.0^{BCb}	25.0±4.2^{ABa}
2012	19.9±1.8^{BCa}	20.3±2.3^{ABa}	23.0±2.6^{ABb}	24.6±3.4^{Aa}
2013	19.2±1.4^{DEb}	20.4±1.6^{ABa}	21.2±2.2^{CDa}	22.4±2.7^{BCa}
2014	18.4±1.5^{FGa}	19.1±1.4^{CDa}	22.7±2.4^{ABa}	23.9±4.3^{ABa}
2015	19.6±1.5^{CDa}	19.4±1.6^{BDa}	22.6±2.8^{ABa}	24.6±3.0^{ABa}
2016	19.3±1.8^{DEa}	19.1±1.4^{CDa}	20.7±1.7^{DEa}	19.9±1.8^{DEa}
2017	19.2±1.7^{DEa}	16.9±1.1^{Eb}	19.9±1.9^{EFa}	22.1±0.7^{ACDa}
2018	18.0±1.6^{Ga}	18.2±1.1^{DEa}	20.7±1.6^{DEa}	21.4±1.7^{CDa}

MFD = Mean fiber diameter; CVMFD= Coefficient of variation of mean fibre diameter; different letters in row (low case) and column (capital letter) are significant.

values for MFD, *e.g.* 27.5 ± 4.6 µm (Aylan-Parker and McGregor, 2002).

The CVMFD is considered a more important index of variability as it accounts for the mean as well as the standard deviation of the alpaca fibre since it affects the processing performance (Badr *et al.,* 2006; Montes *et al.,* 2013). Moreover, this index shows a large dispersion of the wool diameter which confirms that the standard uniformity of the wool goes from average to poor uniformity (Harizi and Abidi, 2015). The magnitude of this index depends upon the location on the animal's body (Aylan-Parker and McGregor, 2002). In the present study, CVMFD showed great variability at the beginning (from 2005 to 2012) of the establishment of the herd.

However, these values tend to stabilize in recent years (from 2013 to 2018) for both white and brown colors alpacas. This trend could be due to the efficient genetic improvement program implemented by CEDAT-DESCO. These values are in agreement with those reported by other authors. In the samples measured from the middle of an animal's side, Aylan-Parker and McGregor, (2002) reported higher average values for CVMFD of 24.3±4.0%, while Montes *et al*. (2013) reported CV < 20% for fibre diameter of nearly 35% of fleeces and greater than 25% for 13% of fleeces. Low values reported in this study for MFD and CVMFD (16.9±1.1 µm and 19.9±1.8%, respectively) indicated that the quality of fibre produced by alpacas from CEDAT- DESCO is of best quality. Results from this study highlighted the efficiency of the program implemented by CEDAT-DESCO, that consequently will contribute with improve the incomes of smallholders when payment is based on fibre quality instead of FW.

Correlation between fibre traits

Pearson's correlation coefficients obtained between FW and MFD and among fibre traits are shown in Table 5. The FW and MFD, as well as CVMFD and MFD had positive significant correlations (0.24 and 0.11, respectively). However, the correlation between FW and CVMFD were not statistically significant (0.08). The positive phenotypic correlation obtained in this study between FW and MFD are greater (0.18) than those reported by Wuliji *et al*. (2000), but in agreement with the results (0.22) reported by Wuliji *et al*. (2019). These results indicated that most of the changes or variation in MFD and FW might be occurred between the first and second shearing time (Wuliji, 2000). These results also suggested that selection towards an increase in MFD might contribute to an increase in FW and CVMFD. However, FW and CVMFD were not correlated.

Table 5: Pearson's correlation coefficient estimates among FW and fiber characteristics in the alpaca herd.

	FW	MFD	CVMFD
FW	-	0.24**	0.08^{ns}
MFD		-	0.11**
CVMFD			-

**Significant association at the *P* < 0.01 level; ns= non-significant association. FW= Fleece weight; MFD = Mean fiber diameter; CVMDF= Coefficient of variation of mean fibre diameter.

CONCLUSION

Results from this study indicated that the FW was influenced by both year of birth and sex, while MFD and CVMFD were influenced by both year of birth and color. The FW and MFD, as well as CVMFD and MFD had positive significant correlations. These results suggested that selection towards an increase of MFD might have an additive effect in both FW and CVMFD. An optimal selection strategy that considers both FW and MFD into a selection index should be adopted to sustain the alpacas breeding programs in the Arequipa Region.

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