Fibre recording systems in camelids

Carlo Renieri[1], Marco Antonini[2] & Eduardo Frank[3]

[1]University of Camerino, Department of Veterinary Science, Via Circonvallazione 93/95, 62024 Matelica, Italy.
[2]ENEA Casaccia, BIOTEC AGRO, Via Anguillarese 301, S. Maria di Galeria, Roma, Italy
[3]SUPPRAD programme, Catholic University of Cordoba, Obispo Trejo 323, Cordoba, Argentina

Keey words: fibre production, fibre characteristics, selection for fibre, suri, recording methodologies.

Introduction

Llama (*Lama glama* L.) and alpaca (*Lama pacos* L.) are domestic mammals classed in the Tilopods suborder together with guanaco (*Lama guanicoe* L.) and vicuña (*Vicugna vicugna* M.). Domesticated by the pre-conquest Andean cultures, they are currently used by South America Andean populations for fiber (both, llama and alpaca), meat and packing (llama) (Flores Ochoa and Mac Quarry, 1995 a, b; Bonavia, 1996).

In order to improve fiber production in both the South American domestic Camelids (SAC), llama and alpaca, three different project have been funded by the European Union during the last 15th years:

- PELOS FINOS, "Supported program to improve Argentinean South American Camelids fine fiber production" (EU DG 1, 1992-1995); involving Argentine, Italy and Spain;
- SUPREME, "Sustainable Production of natural Resources and Management of Ecosystems: the Potential of South American Camelid Breeding in the Andean Region", (EU DG XII, ERBIC18CT960067, 1996-2000) involving 5 South American Countries (Argentine, Bolivia, Chile, Ecuador, Peru) and 4 European Countries (Italy, Germany, France, U.K.);
- DECAMA "Sustainable development of Camelid products and services marketed oriented in Andean region" (E.U. INCO ICA4-CT-2002-10014; in progress), involving Argentina, Bolivia, Peru, Germany and Italy.

Two experiences of selection of fiber production have been carried out during the time of the projects: the selection of llama population on Jujuy Region, Argentina and the selection of the alpaca population in an open nucleus breeding scheme in the Caylloma Region, Perù, involving 18 000 animals and 500 breeders.

Fibre production in alpaca and llama

South American Camelids (SAC) fibre productions are generally divides in Llama and Alpaca fibres. Llama produce less quantity of fibre and present a greater size than Alpaca which is smaller with more ability to produce fibre. Also the commercial classification distinguishes between Llama and Alpaca. In table 1 the quality characteristics in fiber tops of alpaca and llama are presented (Vinella, 1994).

The SAC population presents a great variability and the type of fleece is one of the principal characters utilised to distinguish the different type of animals.

In the Alpaca it is possible to distinguish two different type according fleece structure: Huacaya and Suri. Alpaca "Huacaya" is the more common and is characterized by compact, soft and highly crimped fibres, with blunt-tipped locks which closely resemble those of Merinos sheep. By contrast, the "Suri" has straight, less-crimped fibres and locks with a "cork-screw" shape, very similar to those of Angora goat but not as bright.

The situation in llama is more complicated and different methods of classification according to the different breeding cultural Andean areas exist. A "Suri" type of fleece seems to segregate inside the population, but a "Suri" standardized flocks are never discovered. The dis-homogeneity and the variability of llama flocks derived from the lack of interest on fibre selection by breeders.

Until few years ago llama fleece was mixed with the Alpaca fiber in order to increase the quantity of product, compromising the Alpaca fleece quality of lots. At present, a commercialization of fleece from some "woolly" Llama exists in some Andean highland areas and fiber is directly classified as Llama lots.

Table 1. Quality characteristics in fibre tops of alpaca and llama.

Characterists	Woven goods	Knitwear
Fiber diameter	***	**
Variability of diameter	***	**
Fiber colour	***	***
Colour homogeneity	***	***
Fiber length	**	**
Variability of length	*	*
Dark hair (presence)	***	*
Kemps (presence)	****	*
Presence of impurities	**	**
Regularity tops	**	**
Lustre	***	**
Handle	***	**

Scale: * = Low importance; **** = High importance

The main difference in fleece between alpaca and llama is on the structure: Alpaca has a homotricous fleece in both Huacaya and Suri, while Llama generally presents a double coat structure expressed in different relationship between under coat and outer coat. Llamas is classified in two different types:

1. "*kara*" (or "*cargera*"), typical double coated animal, with many guard hair (outer coat) and markedly less woolly fibres (undercoat) ranging from short to very short, and
2. "*chacos*" (or woolly), single-coated animal with soft, crimped secondary fibres but with a low quality fleece with respect to Alpaca, because many primary fibres are mixed with the secondary ones.

The variation of llama and alpaca fleece is complicated by inter fertility among both and with the wild animals (vicuna and guanaco).

Alpaca and llama should be shorn annually, and expected fleece length and weight would be respectively between 90-160 mm and 3–5 kg (Australian Alpaca Association 1997).

At presents, an homogeneous and official methods to classify the different category of SAC fibres lacks. Generally, industrial classification prefers to grade the fineness according micron rank.

For example the official Peruvian classification is: Baby 20-22 µm; Superfine 25.5 µm; Suri 27 µm; Adult 27.5 µm; Huarizo 32 µm, Llama 34 µm; and Coarse 34-36 µm. Peruvian INCA Tops industry classify the fleece of 2 micron category (<20, 20 – 21, 21 – 22, etc). The Australian classification foresee 5 categories: Superfine (SF) < 22 µm; Fine (F) 22-24.9 µm; Medium (M) 25-29.9 µm; Strong (S) 30-36.9 µm, Coarse (C) > 37 µm.

Selection for fibre production in alpaca and llama

The objectives of selection for fiber production in alpaca and "woolly" llama are:

1. Mendelian characters: type of fleece ("Suri" *vs* "Huacaya") and coat colour;
2. Quantitative characters: fleece weight, fineness and variation of fineness, percentage of medullated fibers, fiber crimp, fiber length, morphological evaluation (linear methodology).

Mendelian characters

Suri

Two different type of fleece exist in SAC: Huacaya and Suri. Huacaya is predominant type and represents the 90% alpaca fleece processed in Peru (Hoffman *et al.*, 1995).

The Suri is characterised by lustrous, silky fibre, with an absence of crimp and the fleece is similar to mohair with particular lustre characteristic. The Suri fleece seems to be dominant with respect to the no–Suri type (Huacaya) (Ponzoni, 1990). However intermediate animals that have no suri and no huacaya fleece structure can be observed when Suri and Huacaya are crossed.

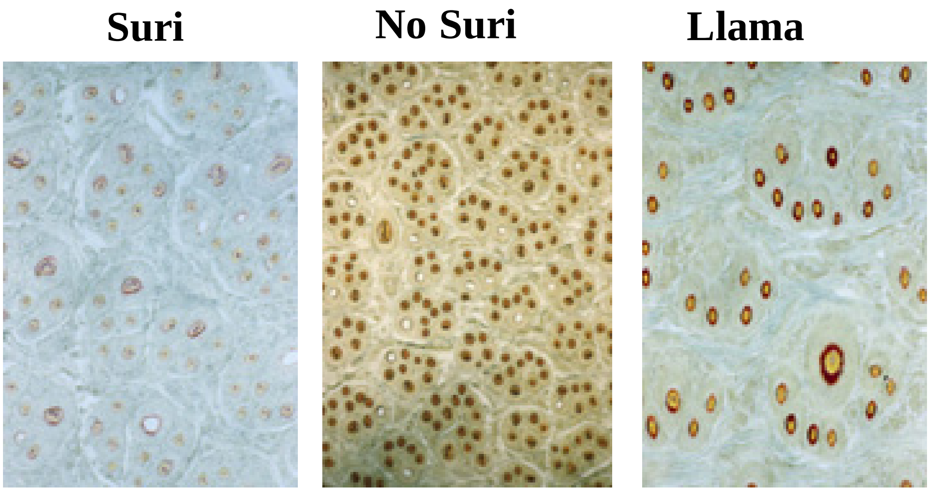

Figure 1. Follicle structure (Antonini et al.*, 2004).*

Among the parameter used to characterise and analyse fibre structure, cell scale frequency could be considered as differential parameter. The range vary from 3 to 18 (Antonini *et al*., 2001).
As described in table 2, 7 Scale / 100 ìm could be the distinctive parameter for Suri fibre. The independence of Suri cell scale frequency from fibre diameter variation under 35 ìm, suggests that this result can be use in selection to achieve single coated structures. The results can be used by textile laboratories in quantitative analysis of blend to differ fibre (Antonini *et al*., 2001).
Fibre Cuticle Cell High presents too low variability to be used as textile distinction tools and a differentiation between the three fleeces types is impossible (Table 3). For this reason Suri lustre and silky characteristic, in comparison with other lustre fibre as mohair, seems depend more by a reduced cuticle cell scale frequency, which gives rise to the typical fibre silky handle, than by the cell scale height. In fact, the cell high value is more similar to Llama and Huacaya with a lower brightness respect to other lustre fibre.
The follicular structure analysis produced some useful information on Suri and Huacaya differentiation. Density of skin follicles, percentage of medullated secondary fibres, and percentage of active secondary follicles reached their maximum values at 2 months in all the three types of SAC (see Table 4) (Antonini *et al*., 2004). The secondary / primary follicles ratio

Table 2. Means scale frequency in fibre cuticle cell.

	All Fibres	Fibres < 35µm	Fibres > 35µm
Suri	7.54	7.50	8.22
No Suri	9.10	9.06	9.28
Llama Woolly	9.72	9.40	10.65

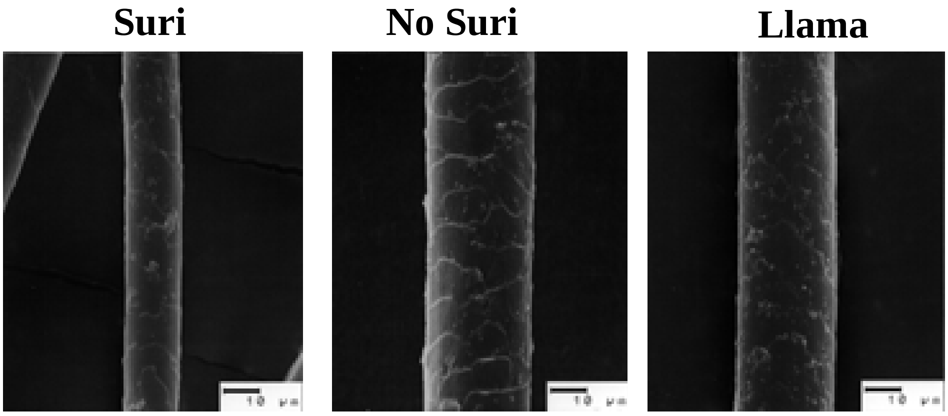

Figure 2. Cuticle structure.

Table 3. Fibre cuticle cell high..

	Means	Max	Min
Suri	0.232	0.05	0.75
No Suri	0.261	0.10	0.55
Llama woolly	0.201	0.10	0.60

(S/P) reaching the maximum value two months later, alpaca Suri and Huacaya and llama gained a complete and mature skin follicle apparatus at an early age.

With reference to the magnitude values of these four parameters, the huacaya and suri alpaca showed similar peak values for follicular skin density and S/P ratio; generally Huacaya presents higher values for both follicular density and S/P respect to Suri. The woolly llama is clearly different from alpaca, exhibiting the lowest values for all parameters (Antonini *et al.*, 2004).

The data presented may be exploited for a rational management of the "crias category". As kid fleece is the most requested by the market, and fibre production potential is present in llama and alpaca from an early age, producers can practise an anticipated first shearing, increasing revenues for animal (one shearing more for productive life).

Table 4. Skin follicular structure.

	Density (n/mm^2)	S/P ratio
Suri	19.90	6.89
No Suri	22.30	8.08
Llama woolly	17.98	4.66

Coat colour

The quality and quantity of melanins that are synthesised in follicular melanocytes determine the colour of hair and wool in mammals. There are two chemically distinct types of melanin pigments: the black to brown eumelanins and the yellow to reddish pheomelanins which are further divided into polymeric pheomelanins and dimeric trichochromes (pheomelanogenesis by-product). It is generally accepted that natural eumelanin is derived from copolymerization of 5,6-dihydroxyindole (DHI) and 5,6-dihydroxyindole-2-carboxylic acid (DHICA) while pheomelanins are characterized by the presence of 1,4-benzothiaziynilalanine structural units which arise biochemically from 3,4-dihydroxy-phenylalanine (DOPA) and cysteine even if pheomelanin-like pigments without sulfur also occur and arise probably by peroxidative cleavage of DHI units of the eumelanin polymer. Eumelanins and pheomelanins are syntethized within melanocytes on the specialized organelle, the melanosome, where the specific enzyme tyrosinase catalyzes conversion of the amino acid tyrosine to dopaquinone. Chemical proprieties of melanins have been described in alpca and llama. The morphology of melanosomes have been described in both llama and alpaca (Renieri *et al.*, 1991; 1995; Cecchi *et al.*, 2001; Cozzali *et al.*, 1998, 2001; Cecchi *et al.*, 2004).

Coat colour variation in llama and alpaca flocks is generally very large and no colour selection has been carried out, except for full white in some peruvian alpaca and argentine llama flocks (Lauvergne, 1994; Mc Quarry, 1995; Renieri, 1995; Lauvergne *et al.*, 2001). The great colour fleece variability is one of the main SAC characteristics. In the industrial cards colour it is possible distinguish 22 different types from white to all brown variable and black.

The variation has been established according to the four phenotypic dimensions; pigment pattern, type of eumelanins, alteration of pigment, type of white designs (Lauvergne *et al.*, 2001). The various phenotypic

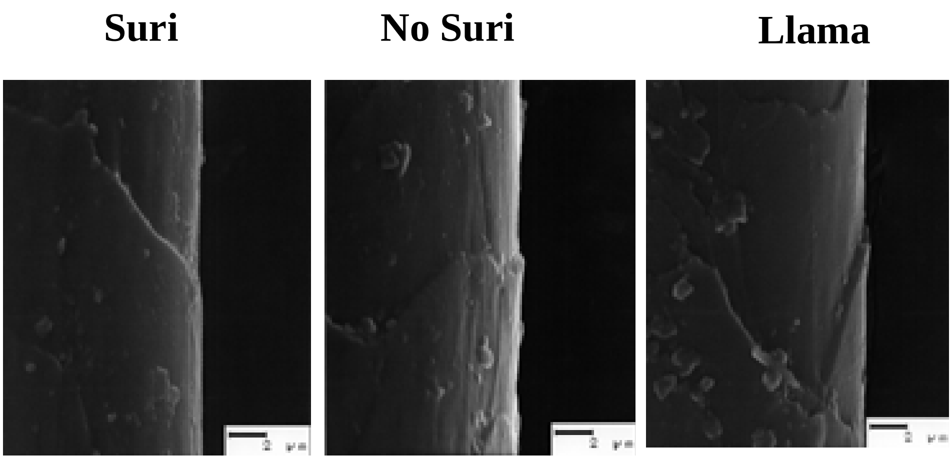

Figure 3. Scale height (Antonini et al., 2000).

variants already identified in llama and alpaca and the inheritance of each variants are given in table 5 (Lauvergne *et al*., 2001; Renieri *et al*., 2002; Frank *et al*., 2002)

According the results of biology and segregations analysis, specific reproductive plans can be carried out for coat colour selection in two alternative ways in llama and alpaca:

1. selection for full dominant white;
2. selection for pigment patterns; in this case, the objectives are:
   a. selection for the uniform patterns: eumelanic black, eumelanic brown and pheomelanic;
   b. selection against no uniform patterns;
   c. selection for grey and greying;
   d. selection against white designs.

Quantitative characters

The following characters can be taken into account as a selection objectives in both llama and alpaca:

- fleece weight at 1st shearing;
- fibre fineness and the variation of fineness at 1st shearing;
- percent of medullated fibres;
- fibre length;
- fibre crimp.

Table 5. Coat colour variations in llama and alpaca.

Dimension		Variants	Inheritance
Pigment pattern	Uniform	Eumelanic	Full recessive *vs* other patterns
		Red (Pheomelanic)	Unknown
	Composed by eumelanic and pheomelanic parts	Eumelanic and tan	Unknown
		Pheomelanic with eumelanic extremities	Dominant *vs* eumelanic and wild patterns
		Mule stripe	Unknown
		Mule stripe with black extremities	Unknown
		Badger face	Unknown
		Wild vicuna	Unknown
		Wild guanaco	Unknown
Type of eumelanins in the eumelanic part		Black	Dominant
		Brown	Recessive
Alteration of pigmentation		Grey	Dominant
		Greying	Dominant
		Dilution	Unknown
		Full White	Dominant and epistatic
White Design		Irregular spotting	Recessive
		Painted	Unknown
		Pack saddle	Unknown

Figure 4. Alpaca.

Figure 5. Llamas.

The very few estimations of genetic parameters for fibre production on alpaca and llama in the original countries are presented in table 6 and 7. The methodology of selection used in both the selection plans (Jujuy and Caylloma) has been the performance test. In both cases an open nucleus breeding scheme has been carried out.

Recording methodologies

Llama and alpaca fiber is tested for fineness by international recognized tests. A test is typically administrated by a recognized laboratory with an expertise in testing fibre. The American Society for Testing and Materials (ASTM) publishes a specification for testing Alpaca fibre.

Table 6. Estimated heritability of fleece characters in alpaca.

Characters	Shearing	Estimated heritability	References
Fleece weight	1st	0.35 ± 0.02	Velasco (1980)
		0.22	Bravo and Velasco (1983)
		0.21 ± 0.07	Roque *et al.*, (1985)
		0.38 ± 0.34	Mamani (1991)
		0.31 ± 0.17	Ruiz de Castilla *et al.*, (1992)
	All	0.79 ± 0.36	Ponzoni *et al.*, (1999)
Fiber diameter		0.18	Leon-Velarde and Guerrero (2001)
		0.67 ± 0.30	Ponzoni *et al.*, (1999)
Staple lenght	1st	0.43 ± 0.39	Mamani (1991)
		0.21 ± 0.07	Roque *et al.*, (1985)
		0.31	Leon-Velarde and Guerrero (2001)
	All	0.63 ± 0.48	Ponzoni *et al.* (1999)

Table 7. Estimated heritability of fleece characters in llama.

Characters	Estimated heritability	References
Fleece weight	0.48 ± 0.02	Choque and Rodriguez (1988)
	0.27	Choque and Rodriguez (1988)
Fiber diameter	0.18	Frank (unpublished)
Staple lenght	0.34 ± 0.08	Choque and Rodriguez (1988)
	0.28 ± 0.37	Choque and Rodriguez (1988)

Fibres fineness, expressed as means fibre diameter, is the most important parameter to define fibre quality in relation to the comfort and lightness of textile product. At the same time the Coefficient of Variation (CV) of the diameter defines the homogeneity of the product, very important for the processing efficiency. ASTM Standards D 2130–90; D 6466–99 and D 6500–00 describe the official method for fineness and CV fibre analysis using respectively Microprojection, Sirolan-Laserscan Fiber Diameter Analyser and Optical Fiber Diameter Analyser.

The presence of medullated fibres and kemp is important dye resistance and light reflectance qualities. Medullated fibre have an abnormally large diameter; an high degree of medulla is probably responsible of low comfort of products (low resistance and “piercing” effect). ASTM Standards D 2968 – 95 defines the official method for medullated and kemp fibres analysis.
The length of fiber affects the quality. A peculiar fibre length is needed by each textile product. However fibre length has less importance in llama and alpaca with respect to other fine fibre producing animals. ASTM Standards D 1575–90 and D 519-04 describe the official method for Fibres length measurement respectively fibre Length of Wool in Scoured Wool and length of fibre in the top.
Fibre crimp is expressed as number waves or crimps per unit length. Crimps affect the carding and subsequent processing of the fibre into either a yarn or a non woven fabric. Staple crimp will also affect the bulk or openness of a yarn and therefore the hand and visual appearance of the finished textile product. In llama and alpaca fibre crimp is one of the more important distinctive parameter. ASTM Standards D 3937-90 describes the official method for Crimp Frequency of staple fibres. Unpublished data provided by the INCA Tops Peruvian Factory, show a significant difference between the Suri crimp (20.60) and other different non Suri fibre (Royal Alpaca – 39.00; Baby Alpaca - 34.40 and Superfine Alpaca - 32.57)

References

Antonini M., Gonzales M. and Valbonesi A, 2004. Relationship between age and postnatal skin follicular development in three types of South American domestic camelids. Livestock Production Science (2004) (In Press).

Antonini M., Gonzales M., Frank E., Hick M., Pierdominici F., Catalano S. and Castrignanò F, 2001. Cuticle cell mean scale frequency in different type of fleece of domestic South American Camelids. Progress in South American camelids research. EAAP publ. no. 105, pp. 110-116.

ASTM D519-04, 2001. “Standard Test Method for Length of Fibre in Wool Top”. ASTM International.

ASTM D1575-90, 2001. “Standard Test Method for Fibre Length of Wool in Scoured Wool and in Card Sliver”. ASTM International.

ASTM D2130-90, 2001. “Standard Test Method for Diameter of Wool and Other Animal Fibres by Microprojection”. ASTM International.

ASTM D2968-95, 2001. “Standard Test Method for Med and Kemp Fibres in Wool and Other Animal Fibres by Microprojection”. ASTM International.

ASTM D3937-01, 2001. “Standard Test Method for Crimp Frequency of Manufactured Staple Fibres”. ASTM International.

ASTM D6466-99, 2001. "Standard Test Method for Diameter of Wool and Other Animal Fibres by Sirolan-Laserscan Fiber Diameter Analyser". ASTM International.

ASTM D6500-00, 2001. "Standard Test Method for Diameter of Wool and Other Animal Fibres Using an Optical Fiber Diameter Analyser". ASTM International.

Australian Alpaca Association Inc, 1997. Guide line for Alpaca Clip preparation.

Bravo W. and Velasco J., 1983. Indices de herencia de pesos al nacimiento, al destete y primiera esquila in alpacas. Compendio de resumen de Proyecto de Investigacion UNMSM, Tomo III, Lima, Peru.

Bonavia D., 1996. Los Camelidos Sudamericanos [South American Camelids]. Lima: IFEA-UPCH-Conservation International, p. 1-843.

Carpio Pino M. and Santana Chavez P., 1982. Estudio preliminar de la longitud y analisis cuticular en la fibra de vicuna. Informe de trabajo de investigacion en vicuna vol 1, 1-53.

Cecchi T, Passamonti P, Frank EN, Gonzales M, Pucciarelli F and Renieri C., 2001. Pigmentation in South American Camelids: I Quantification and variation of combined eumelanins and pheolelanins in various coat colours. In: Gerken M., and Renieri C. Progress in South American camelids research. Wageningen. EAAP publ. no. 105, pp. 207-210.

Cecchi T., Cozzali C., Passamonti P., Ceccarelli P., Pucciarelli F., Gargiulo A.M., Frank E., Renieri C., 2004. Melanins and melanosomes from llama (*Lama glama* P.). Pigment Cell Res. 17: 307-311.

Choque F. and Rodriguez T., 1988. Determinacion de parametros geneticos en caracteres de produccion de carne y fibra wn Llamas. Proc. VI Conv. Int. Especialistas en Cam. Sud., Oruro, Bolivia (Abstract).

Cozzali C, Dell'Aglio C, Gargiulo AM, Frank E, Hick M, and Ceccarelli. 2001. Morphological features of follicular melanocytes. In: Gerken M., and Renieri C. Progress in South American camelids research. Wageningen. EAAP publ. No 105, pp. 237-238.

Cozzali C., Lorvik S., Ceccarelli P. and Renieri C., 1998. Ultrastructural features of melanocytes from South American domestic Camelids. Proc. Italian Society of Veterinary Science (SISVet)., LII, 41-42

Flores Ochoa J and Mac Quarry K, 1995. I Camelidi andini. [South American Camelids]. In F.O. Patthey and Sons, L'oro delle Ande [The Gold of Andes], vol. I°, J. Soto Impresor, Madrid, Spain, 22-35.

Flores Ochoa J and Mac Quarry K, 1995. Pastorizia andina contemporanea. [Actual Andean breeding]. In F.O. Patthey and Sons, L'oro delle Ande [The Gold of Andes], vol. I°, J. Soto Impresor, Madrid, 100-193.

Frank EN, Renieri C, Hick MVH, La Manna V, Gauna CD and Lauvergne JJ., 2002. Segregation analysis of irregular spotting and full white in llama. In: Proc. 7th WCGALP. Montpellier, France. Comm. 12-17.

Hoffman E. and Fowler M.E., 1995. The Alpaca book. Clay Press Inc., Herald, California: 82.

Lauvergne J.J., 1994. In: Gerken M and Renieri C., 1994. Proc. Europ. Symp. South Am. Cam.. Camerino. pp. 59-63.

Lauvergne JJ, Marinez G, Ayala C and Rodriguez T., 2001. In: Gerken M., and Renieri C. Progress in South American camelids research. Wageningen. EAAP publ. No 105; 2001. pp. 64-74.

Leon-Velarde C.U. and Guerrero J., 2001. Improving quantità and qualità of Alpaca fiber, using a simulation model for breeding strategies. In:*http://inrm.cip.cgiar.org./home/publicat/01cpb023.pdf*

Mc Quarrie K, 1995. Industria e commercio. [Industry and trade]. In F.O. Patthey and Sons, L'oro delle Ande [The Gold of Andes], vol. I°, J. Soto Impresor, Madrid, 292-347.

Ponzoni R.W., Hubbard D.J., Kenyon R.V., Tuckwell C.D., McGregor B.A., Howse A., Carmichael I., Judson G.J., 1997. Phenotypes resulting from Huacaya by Huacaya, suri by Huacaya and suri by suri alpaca crossino. Proc International Alpaca Industry Seminar, Sydney, pp. 11-13.

Renieri C., Trabalza Marinucci M., Martino G., Giordano G., 1991. Indagine preliminare sulla qualità del pelo e sul colore del mantello in soggetti alpaca (*Lama glama pacos* PF) pigmentati. [Preliminary report on quality of hair and coat colour in pigmented alpaca]. Proc IX Nat. Congr. Italian Association of Animal Production (ASPA), 905-914.

Renieri C., Lauvergne J.J., Antonimi M., and Lundie R., 1995. Quatitative determination of melanins in black, brown, grey and red phenotypes of sheep, goat and alpaca. Proc. 9th Int. Wool Textile Res. Conf., Vol. II, 580-586.

Renieri C, Frank EN, Hick MVH, La Manna V, Gauna CD and Lauvergne JJ., 2002. Segregation analysis of coat colour phenotypes in llama. In: Proc. 7th WCGALP. Montpellier, France. Comm. 12-16.

Renieri C., Lauvergne J.J., Antonini M. e Lundie R., 1995. Quantitative determination of melanins in black, brown, grey and red phenotypes of sheep, goat and alpaca. Proc. 9th Int. Wool Textile Res. Conf., II, 580-586

Roque J., Carpio M. and Blackwell R., 1985. Transmision hereditaria de peso vivo y longitude de mecha en alpacas. V Conv. Int. Esp. Cam. Sud., Cuzco, Peru.

Ruiz de Castilla M., Alagon Huallpa G. and Quirita Bejar C.R., 1992. Estudio de parametros geneticos en alpaca Huacaya. Informe de trabajos de Investigacion "Alpaca y Llama de color", Vol. II, 1-28.

Velasco J., 1980. Heredabilidades y correlaciones de peso corporal y peso del vellon en alpacas. Anales III eunion Ass. Peruana Prod. Anim. (APPA), Lima, Peru (abstract).

Vinella S., 1994. The European market of South American Camelid wool. In Gerken M. and Renieri C., European Symposium on South American Camelids, Camerino, pp. 155-166.