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Quality characteristics of alpaca (*Vicugna pacos*) fiber. As an indicator of its commercialization Características de calidad de la fibra de alpacas (*Vicugna pacos*). Como indicador de su comercialización

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Article Data

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Abstract

To evaluate the main characteristics of alpaca (*Vicugna pacos*) fibre quality as an indicator of its marketability, this research was carried out between June and July 2022, in the province of Cotopaxi, Ecuador. Sixty alpacas were selected from 12 communities. The diameter, length, fibre categorization and fleece weight were taken from existing records; except in Salache, where 10 ± 0.1 g of fibre was collected from the animals' left midribs. The fibre was classified and its marketing category was determined, according to the marketing company. Descriptive statistics were obtained for each variable. The lowest diameter values corresponded to Apahua ($16.06 \pm 1.30 \mu\text{m}$) and the highest to Salache ($32.00 \pm 3.26 \mu\text{m}$). The longest fibre length was found in the alpacas of Salache (15.56 ± 1.10 cm) and in the rest of the communities it ranged from 9.16 to 13.16 cm. The highest average fleece weight was obtained in Salache (4.25 ± 0.45 kg) and the lowest in Maca Chico (1.89 ± 0.18 kg). In the Kum company, the Sacha community contributes 48.87 % of the extra fine fibre, and 44.14 % of the total. In the Pacocha company, the Apahua community contributed 43.37 % of the total fibre and 26.15 % of the superior quality fibre. It can be concluded that the fibre from the alpacas of Apahua has the smallest diameter, length and fleece weight. This community sold the highest quality fibre

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Resumen

Para evaluar las principales características de la calidad de la fibra de alpacas (*Vicugna pacos*), como indicador de su comercialización, se desarrolló esta investigación entre junio y julio del 2022, en la provincia Cotopaxi, Ecuador. Se seleccionaron 60 alpacas, de 12 comunidades. El diámetro, longitud, categorización de la fibra y el peso del vellón se tomaron de los registros existentes; excepto en Salache, donde colectaron 10 ± 0.1 g de fibra del costillar medio izquierdo de los animales. La fibra se clasificó y se determinó su categoría de comercialización, según la empresa comercializadora. Se obtuvieron los estadígrafos descriptivos de cada variable. Los valores más bajos del diámetro correspondieron a Apahua ($16.06 \pm 1.30 \mu\text{m}$) y los más elevados a Salache ($32.00 \pm 3.26 \mu\text{m}$). La mayor longitud de la fibra la tuvieron las alpacas de Salache (15.56 ± 1.10 cm) y en el resto de las comunidades estuvo en un rango de 9.16 a 13.16 cm. El peso promedio más alto del vellón se obtuvo en Salache (4.25 ± 0.45 kg) y el más bajo en Maca Chico (1.89 ± 0.18 kg). En la empresa Kum, la comunidad Sacha aporta el 48.87 % de la fibra extrafina, y el 44.14 % del total. En la empresa Pacocha la comunidad Apahua aportó el 43.37 % de la fibra total y el 26.15 % de la de calidad superior. Se concluye que la fibra de las alpacas de Apahua presentan los menores diámetro, longitud y peso del vellón. Esta comunidad vendió la fibra de mayor calidad

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Introduction

The alpaca (*Vicugna pacos*) inhabits high Andean areas above 3000 m.a.s.l. in Peru, Bolivia, Ecuador, Argentina and Chile¹. It is the most important species in the South American camelid family (SAC), and since its domestication 7000 years ago, it plays an important role in the economy of more than 165000 families in 25000 rural communities, which depend on the commercialization of its fibre as their main or only source of income².

Alpaca fibre (AF) is highly accepted worldwide for the textile industry, its trade and price depend on its quantity and quality. The latter is determined by its diameter, length and fleece weight³, so these characteristics indicate the possibilities and success in its commercialization, and must be periodically evaluated in order to adopt zootechnical and management measures to benefit them.

The fleece is the coat covering the alpaca, consisting of fine and coarse fibres, the most valued portion of the animal and is positively correlated with fibre diameter (FD)³. Heavier fleeces of fine fibres are worth more than lighter fleeces of coarse fibres, with an estimated cost of production of 3.0 and 5.0 USD, under extensive rearing conditions¹.

Fleece quality is mainly classified by FD⁴, hence the reduction of the latter is one of the aspects that receives most attention in order to genetically improve the species⁵. Additional parameters are the coefficient of variation of FD⁶, comfort factor¹, curvature index⁷, tensile strength⁸.

The FD of alpaca varies from 12 to 28 μm ^{3,9,10}, there is a positive correlation between fibre diameter and fibre length, both parameters are indicators to obtain the raw material, and determine the manufacturing properties for the spinning mill, as well as define the final price of the fibre¹¹.

AF in the communities of Cotopaxi Province is acquired by the companies Kum (Kum fibras, Quito - Ecuador) and Pacocha (Lima - Peru) according to their category, which is granted according to the technical standards NTP 231.300.2014 and NTP 231.301.2014, respectively (NTP)¹².

The sale of fibre at low and fluctuating prices means little income for the breeders and leads to the indiscriminate removal of animals. In order to improve the economic income of the breeders, FMF collection centres have been set up in Ecuador, but these are insufficient¹³.

There are no updated official statistics to characterize the quality, productivity, trade and destinations of AF production in Cotopaxi Province, Ecuador, and consequently, there is no precise scientific information on these aspects in the alpaca communities of this Ecuadorian region.

The objective of this research was to evaluate the main characteristics of alpaca (*V. pacos*) fibre quality as an indicator of its commercialization in the province of Cotopaxi, Ecuador.

Materials and methods

The study was conducted between June and July 2022, in the province of Cotopaxi, Ecuador; in the 5 main alpaca breeding communities: Maca Chico, Maca Grande, Apagua, Sacha and Salache, belonging to the cantons of Latacunga 0° 55' 60" south latitude (LS) and 78° 37' 0" west longitude (LW), Pujilí 0° 57' 0" LS and 78° 41' 24" LW and Salcedo 1° 3' 0" LS and 78° 34' 60" LW.

In general, the research scenario has an altitude between 2735 and 4000 m.a.s.l., average temperature of

12 to 16° C, average annual rainfall fluctuating between 1626 and 1946 mm. Table 1 shows the particular edaphoclimatic conditions of each community¹⁴.

The animals were fed on natural grasses predominant in the communities.

Table 1 Average annual edaphoclimatic conditions of the communities under study

Community	Altitude (m.a.s.l.)	Average temperature°C	Fluvial precipitation (mm)
Apahua	4000	12	1946
Maca Chico	2000 a 3000	9 a 18	800 a 2000
Maca Grande	2000 a 3000	9 a 18	800 a 2000
Sacha	3360	15 a 28	625
Salache	2735	16	1626

Sixty alpacas (*V. pacos*) between 6 and 8 years of age, 30 females and 30 males, clinically healthy, 12 for each community or production center, 6 of each sex, were selected to be evaluated for the first time for their fiber quality characteristics. The sample size was calculated considering the variability of the parameters to be investigated, obtained in previous research.

From the communities of Maca Chico, Maca Grande, Apagua and Sacha, data on diameter, length, fiber categorization and fleece weight were taken from existing records. From the community of Salache, 10±0.1 g of fiber were collected from the left midrib of each alpaca, deposited in airtight polyethylene bags and sent to the Ministry of Agriculture, Aquaculture and Fisheries (MAGAP) in Riobamba. The diameter, length, and weight of the fleece were determined according to the procedures described by Huanca et al.¹⁵.

The fiber was classified according to NTP¹² and the category of the marketed fiber was determined, in the

communities of Maca Grande, Maca Chico and Sacha, according to NTP¹³, by the company Kum (Kum fibras, Quito - Ecuador) and for those of Salache and Apahua, according to NTP¹², by the company Pacocha (Lima - Peru).

Statistical processing. Descriptive statistics were obtained for each variable: mean, standard deviation, coefficient of variation, minimum and maximum. The Statgraphics Centurion XVI¹⁶ statistical package was used for all processing.

Results

Fiber diameter analysis. Table 2 shows the descriptive statistics of the FD, note that the lowest average values correspond to the Apahua community, the highest to Salache, both communities have a greater dispersion of values, which are far from Maca Chico, Maca Grande and Sacha.

Table 3 shows the classification of AF, according to average diameters, considering NTP¹².

Table 2 Average fiber diameter (µm) of alpacas in the communities studied

Community	\bar{x}	SD	Median	CV (%)	Minimum	Maximum
Apahua	16.06	1.30	16.80	8.09	8.80	24.00
Maca Chico	23.20	0.58	23.10	2.50	19.60	26.20
Maca Grande	23.96	1.11	22.85	4.63	17.10	31.60
Sacha	22.19	1.01	22.25	4.55	17.1	26.6
Salache	32.00	3.26	32.00	10.18	20.00	60.00

Table 3 Classification of alpaca fibers, according to average diameters (μm)

Community	\bar{x}	Classification	Criteria of the NTP 231.301.2014 ¹²
Apahua	16.06	Alpaca Súper Baby	Diameter $\leq 20 \mu\text{m}$ and its length minimum average length is 65 mm
Maca Chico	23.20	Alpaca Fleece	Between $23.1 \mu\text{m}$ and $26.5 \mu\text{m}$ and their average minimum length is 70 mm
Maca Grande	23.96	Alpaca Fleece	
Sacha	22.19	Alpaca Baby	Diameter from 20.1 to $23 \mu\text{m}$ and its average minimum length is 65 mm. average minimum length is 65 mm
Salache	32.00	Alpaca gruesa	Diameter $> 31.6 \mu\text{m}$ and its average length is minimum is 70 mm

Fiber length analysis. In Table 4, the average length of AF is shown, and it can be seen that it is greater in the Salache community with 15.66 cm and in the rest

of the communities it is in a range of 9.16 to 13.16 cm. In the Salache community the variability was greater.

Table 4 Average fiber length (cm) of alpacas in the communities studied

Community	\bar{x}	SD	Median	CV (%)	Minimum	Maximum
Apahua	9.32	.52	9.65	5.57	7.80	11.00
Maca Chico	9.16	.56	9.00	6.11	6.50	13.00
Maca Grande	13.16	.52	13.50	3.95	10.50	16.00
Sacha	11.66	.69	11.75	5.91	8.50	17.00
Salache	15.56	1.10	16.00	7.02	10.00	24.00

Table 5 Fleece weight (kg) of alpacas in the communities studied

Community	\bar{x}	SD	Median	CV (%)	Minimum	Maximum
Apahua	3.25	.17	3.05	5.23	2.30	4.20
Maca Chico	1.89	.18	1.75	9.52	.90	3.00
Maca Grande	2.26	.20	2.30	8.84	1.30	3.2
Sacha	2.35	.29	2.3	12.34	1.00	4.70
Salache	4.25	.45	4.25	10.58	2.00	6.60

Table 6 Fiber purchased by the company Kum (Kum fibras, Quito - Ecuador), by categories NTP¹²

Community	Fiber (kg)				
	Extrafine	Fine	Semifine	Thick	Total
Maca Grande	3.30	7.30	9.50	7.20	27.30
Maca Chico	5.80	6.20	.00	10.80	22.80
Sacha	8.70	5.50	10.50	14.90	39.60
Total	17.80	19.00	20.00	32.90	89.70

Table 7 Categorization of the fiber purchased by the company Pacocha (Lima - Peru), NTP¹²

Community	Fiber by category (kg)					
	Baby	Fleece	Huarizo	Thick	Cut	Total
Salache	1.62	7.10	12.30	3.20	26.70	50.92
Apahua	8.50	1.70	13.20	2.80	12.80	39.00
Total	10.12	8.80	25.50	6.00	39.15	89.92

Fiber productivity analysis. Table 5 shows the values of fleece weight (productivity). The highest average was observed in Salache with 4.25 kg, followed, in

descending order, by Apahua which produces 3.25 kg, Sacha with 2.35 kg, Maca Grande 2.26 kg and in last place Maca Chico with 1.89 kg.

Fiber distribution. Table 6 shows the categorization of the AF according to the company Kum (Kum fibras, Quito - Ecuador), note that in the community Sacha 8.70 kg of extra fine fiber were marketed, followed, in descending order, by the communities of Maca Chico 5.8 kg and Maca Grande of 3.3 kg. Likewise, Sacha reaches the best yields since it contributes the highest amount of total fiber, 39.60 kg.

Table 7 shows the classification of the fiber purchased by the Pacocha company (Lima - Peru). The Salache community provided the greatest amount of fiber, 50.92 kg, and Apahua sold the least amount of fiber, 39.00 kg.

Discussion

Fiber diameter analysis. The value of the coefficient of variation of the FD, indicated uniformity of this parameter in the animals⁶. Therefore, the most uniform fibers are those of the alpacas from the Maca Chico community and the least uniform are those of the animals from Salache, followed by those from Apahua (Table 2).

The variability of the average FD values of alpacas between communities is due to factors that interact and change within communities, such as diet¹⁷, geographic location⁴, sex^{10,18,19}, physiological state, rainfall, age of the animals^{6,20} and breed¹⁰. These aspects could influence the variability of FD, but must be studied with experimental designs to arrive at conclusive results.

Our results corroborate those of Huanca et al.¹⁵ and Llactahuamani et al.¹⁰ who observed highly significant differences in FD between communities in Peru. Apahua alpacas have an average diameter of 16 μm (Table 2), which may be due to the existence of younger animals, which produce a fleece with finer

fibers, due to the effect of shearing, which increases the function of the follicles¹⁰.

The FD of Apahua (Table 2) was similar to that obtained in alpacas younger than 1-year-old. In Peru, the same was 17.86 and 18.23 μm ²⁰, and 18.88 μm ⁶. In Chimborazo, Ecuador, it had values of 9.68 and 17.85 μm ⁹.

There is a positive correlation between alpaca age and FD, reported in the United States, lower FD were observed in young animals, which increased with increasing age⁹. Similar results were reported by Quispe et al.¹¹ for mean fiber diameter and strand length of Huacaya alpacas from La Raya Experimental Center.

Regardless of the location of the studies, a directly proportional relationship is reported between the average fiber diameter and age of the alpacas^{3,11,18,21-24}. The average FD of Maca Chico, Maca Grande and Sacha (Table 2), indicate that the animals evaluated are adults and their values correspond to those reported by other authors⁶, who report 22.79 μm ²⁵ and 24.12 μm for this variable in alpacas from Huanavelica, Peru.

Another factor that influences the FD is sex, but the results are contradictory, Carhuapoma et al.²⁵ observed that males have a smaller diameter than females; however, Quispe et al.¹¹ did not observe the influence of sex on the FD.

According to Franco et al.²⁶ the nutrition of alpacas affects their fiber yield on a larger scale, especially during periods of the year when food is scarcer. Although there is no exact data on the nutrition of the animals involved in this study, their basic diet was based on pasture and their phenological cycle, and their nutritional quality is influenced by the edaphoclimatic conditions of the regions where the communities are located^{23,27}.

The FD also depends on the technique used for its determination¹¹. In this research, it was determined by the Lanometer technique in the community of Salache, and is the cause of its higher values, with this procedure a portion of each sample is introduced through folds in the Hardy Microtome and cuts are made to the fiber with a scalpel blade, dropping them on an object holder¹⁵.

Other authors propose that the diameter varies between and within the fibers, due to various factors, not yet fully clarified²⁸. One of them is the lack of uniformity in the FD, at different points along the length^{11,21}. Although this aspect was not controlled, or is not known, it is one of the causes of the variation in FD observed between communities (Table 2).

The FD is the most relevant characteristic for determining quality, and the lower the FD, the higher the price in the market⁴. Currently, fiber production has decreased due to the variability in its diameter, motivated by the fact that it is not uniform along its length, which has repercussions on fiber quality^{11,21}. According to the average diameters, and considering the NTP¹², which establishes that the fibers whose diameter is less than 26.5 μm , with a minimum length of 65 mm, and which are not brittle, present superior qualities, the communities of Maca Chico and Salache presented lower fiber quality.

In this research it was pointed out that the finest fibers have higher quality, which corroborates that this is the characteristic that most influences its classification and, therefore, its commercialization value¹¹. In this sense, the factors that influence its diameter should be controlled, which will allow carrying out zootechnical and management actions so that it is maintained with optimum values. In addition, this parameter should be considered as one of the main criteria for the selection of parents.

Fiber length analysis. The AF in Sacha, Maca Chico and Apahua have a conformable length (Table 4) and indicate that shearing was carried out in a period of 1 year, considering a fiber growth of 8 to 12 cm per year⁵. These authors state that the length and diameter of the fiber are parameters that determine its manufacturing properties. Apahua fiber meets the standards according to diameter and length (Tables 2 and 4), classifying it as a quality fiber (Table 3).

In Apahua and Maca Chico the fiber length (Table 4) was similar for both sexes and for the 3-year-old animals, but shorter than that of the 1-year-old alpacas and longer than those over 3 years of age¹¹, these authors observed an inversely proportional relationship between age and fiber length.

With respect to Flores Hualpa²⁹, he refers to lower fiber length in alpacas from the communities of Apahua and Maca Chico, similar to Sacha and greater in Maca Grande and Salache. The fiber length of the animals from Maca Grande, Sacha and Salache were superior to that described by Quispe *et al.*¹¹.

Length is the characteristic that follows diameter in importance and both are indicators for obtaining the raw material, which determine its manufacturing properties for spinning the textile material and deciding whether it will be subjected to carding or combing³⁰, as well as defining its final price³¹. Both dimensions are appreciated when analyzing the quality of the fiber produced³⁰. Therefore, the factors that influence its length should also be specified and this characteristic should be considered in alpaca genetic improvement programs.

Analysis of fiber productivity. The alpacas of the Salache community (Table 5) had greater fleece weight and FD (Table 2), since these indicators have a positive correlation that varies between 0.12 to 0.47^{21,32,33}. However, in Apahua and Maca Chico this

relationship was not fulfilled, in the former the alpacas had the fibers with the smallest diameter (Table 2), even though their fleeces had the fourth highest fleece weight in ascending order (Table 5). On the contrary, in the second, the animals had the third largest diameter in ascending order and the lightest fleeces (Tables 2 and 5).

The above results are contradictory and there are no conclusive studies on the causes of variability in the correlation between fleece weight and FD. Consequently, these aspects should be considered in future research, which could provide novel and very interesting scientific and practical results, due to the importance they could have on the quality and marketing value of the fiber, and in alpaca genetic improvement programs.

Quispe et al.¹¹ stated that fiber trade is a function of its quantity, but also of its quality, with heavier, fine-fiber fleeces costing more than lighter, coarse-fiber fleeces. According to this approach, the Apahua production center has the best fleece weight to DF ratio and, therefore, higher quality.

There are differences in the quality of AF, depending on where the animals come from, since each locality or region has its own characteristics. Fiber quality will be more influenced by age, fleece color, community of origin of the animals than by sex, and the body zone where the sample was taken³.

The quality of AF differs according to the place of origin, since each locality, region or community has its own characteristics, including soil and climatic conditions, breeds, genetic improvement and feeding conditions³.

For these reasons, in order to increase the quantity and quality of AF, it is necessary to know and carry out primary and support activities to learn about,

identify and analyze the different stages that are necessary to optimize the production process, especially production and marketing, in order to optimize them and generate greater benefits for producers².

Fiber distribution. The company Kum (Kum fibras, Quito - Ecuador) buys alpaca fiber from the communities Maca Grande, Maca Chico and Sacha, and the company Pacocha (Lima - Peru) buys alpaca fiber from Salache and Apahua. The first company purchases fiber using NTP¹³, which establishes four categories: extrafine, fine, semi-fine and coarse. The second company purchases fiber according to NTP¹², under 5 categories: Baby, Fleece, Huarizo, Coarse and short.

Of the fiber marketed in the company Kum (Kum fibras, Quito - Ecuador), the Sacha community contributes 48.87 % of the extra-fine fiber, the best quality fiber and 44.14 % of the total wool among the communities studied (Table 6). On the other hand, Pacocha (Lima - Peru), from the Salache community, contributed 56.62 % of the total, of which only 17.51 % (8.72 kg) is classified as superior quality (Baby and Fleece), according to NTP¹². That amount represented 46.08 % of the wool marketed with that classification, of which Apahua marketed 26.15 % of its wool (Table 7). This is in correspondence with the fiber classification according to diameter and length, Tables 2 and 4.

The commercialization of AF has a limited economic contribution, which is a limitation. The alpaqueros shear and categorize the fiber, and only two companies have been identified that are interested in buying the product, each with different conditions according to their categorization¹².

The company Kum (Kum fibras, Quito - Ecuador) pays USD 6 for the best quality and USD 3 for the coarse fiber, while Pacocha (Lima - Peru) pays USD

18 for the best fiber and USD 0.25 for the rest. In addition, they do not buy the panties of the legs.

The final product with denomination of origin and the necessary certifications by qualified international organizations, which recognize the quality and sustainability of the fiber used, will surely allow its entry into an elitist market with high prices. These two axes, together with the work of a technically efficient industry, could close the circuit of a competitive and economically profitable chain³⁰.

In most associations there are genetic problems due to incorrect management of inbreeding and mating of alpacas, which limits and hinders the production of good quality AF garments. As a consequence of these frequent problems, sometimes only a coarse fiber is obtained, which can also be used to make garments, but without the shine, texture and finish required to be sold on the French market. The greasy fiber, as well as the coarse fiber are transferred in the sales to the sweep, but at a low price³⁰.

It was concluded that, of the communities evaluated, the Apahua AF had the lowest diameter (16.06 μm), length (9.32 cm) and fleece weight (3.25 kg), while in Salache these parameters were the highest, 32 μm , 15.66 cm and 4.25 kg, in the same order. Both territories marketed the fiber in the Pacocha company (Lima - Peru), Apahua and Salache sold 26.15 % and 17.51 % of the fiber with the superior quality. In the company Kum (Kum fibras, Quito - Ecuador) the Sacha community contributed 44.14 % of the total fiber and 48.87 % of the highest quality, the extrafine.

The results of this research provide alpaca producers with the necessary tools to select animals with the best characteristics for the quality and commercialization of alpaca fiber, with superior economic value and to establish management programs and zootechnical measures that benefit them. In addition, select

elite animals in the production of fiber and include them in genetic improvement programs of alpaca population.

Source of financing

It should be emphasized that the financing of the research project "Characterization of the productivity and distribution of alpaca (*Vicugna pacos*) fiber in the Province of Cotopaxi" was financed with the researchers' own resources.

Conflicts of interest

The authors declare that they have no potential conflicts of interest with respect to the authorship and/or publication of this article.

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Ethical considerations

Retrospective data were used and the fiber sample in the Salache alpacas was obtained respecting the European norms indicated in (https://ec.europa.eu/environment/chemicals/lab_animals/legislation_en.htm) for the use of animals in research.

Authors' contribution to the article

The contribution of each of the authors was: *Luis Alonso Chicaiza Sánchez*, information search, study

design, data collection, writing of the draft. *Rafael Alfonso Garzón Jarrin*, information search, data collection, writing and editing of the document, *Patricia Marcela Andrade Aulestia*, data collection, data processing and analysis, writing and editing of the document.

Research limitations

Fiber parameters are not statistically compared between the communities studied and reference parameters are not established for them because the necessary number of our samples were not processed.

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