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Properties and Structure of Polish Alpaca Wool

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Abstract
This paper reports on the structure and most significant parameters of wool from alpacas bred in Poland. The external and internal structures of the fibre were evaluated based on microscopic observations of the fibre surface and cross sections. It was determined that both the surfaces and cross sections of the alpaca fibres show differences when compared to wool fibres. The diameter, which is the most important fibre parameter, was measured using three methods (including the Laser-Scan method).Investigations were made on 15 samples taken from various alpacas from a herd of 120 animals. Depending on the investigation method used, certain differences in the fibre diameter were observed. An analysis showed that the results of measurements of alpaca wool diameter best correlate when using the scanning electron microscopy and Laser-Scan methods. Large variations in the fibre thickness of the various samples prove the non-uniformity of wool from the whole alpaca herd, indicating that alpacas are bred in an uncontrolled (random) way.

Key words: *alpaca wool, length fibre, linear mass, breaking tenacity, elongation, diameter, fibre surface, cross sections.*

RESEARCH AND DEVELOPMENT

Introduction

Alpaca is a mammal of the order of Artiodactyls - the camel family. Man controls territories where domesticated camelids, such as lamas and alpacas live. But so far they have included primarily the zone of the Altiplano region of Peru, Bolivia and Chile in South America. The world population of Alpacas is estimated at 4 million heads [1]. In Peru the number of alpacas has reached 3.3 million, in Bolivia - 420 thousand and in Chile there are an estimated 45 thousand . The breeding of alpacas started on other continents at the beginning of the 80s. Currently, the largest number of these animals, apart from South America, is found in Australia (over 100 thousand.), USA, Canada, New Zealand and some countries of Europe.

In Europe, the breeding of alpacas is in such countries as the United Kingdom (20 thousand heads), Switzerland, Germany, Austria, France, Spain, Poland and some Scandinavian countries [1].

There are two alpaca breeds: the huacaya and suri [1, 2, 4]. They have a different appearance and type of fleece. The huacaya has wool similar to that of sheep, with small crimps and a yearly fibre growth of 9 - 12 cm. Suri alpaca wool is more delicate than that of huacaya wool, has more luster and a yearly fibre growth of 10 - 12 cm. Alpacas are kept mainly for their wool, which has particularly high quality and end use properties. Alpaca wool is light, cool, and, at the same time, protects well against cold.

Alpaca fibre is a natural fine and soft product that has more than 17 natural black white and brown colours. Those who wear Aplaca garments choose them because of their thermal qualities and resistant features of the fibre, as well as some other attributes such as their impermeability and antiinflamability.

The problem is partly known from a few publications in world literature, but so far there have been no complex studies of alpaca wool processing – 'from fibre to product'.

At the world conference in Bradford, Villarroel [6] presented the most comprehensive information so far concerning alpaca wool and its future textile applications. He indicated many problems which also refer to big variations in fibre thickness, depending on the fibre location on the animal's body. Rainsford [7] emphasises that in Peru garments made from alpaca wool have been traditionally used for a long time. According to Rainsford [8], there is growing concern in Peru over the continuous thickening of alpaca fibres (over 31 μm) whilst the supply of thinner fibres (20 - 26 μm) is smaller and smaller. This is happening since Peru does not have a national record of alpaca population and no control of fibre thickness.

Comparative studies of fibres from alpaca, lama, vicuna and guanaco were presented by Greaves and Rainsferd in their paper [9]. The comparison was done for the years 1970 and 2005. They stated that there was a significant increase in fibre thickness in comparison to the results from the year 1970.

Alpacas was introduced to Poland seven years ago. From year to year their population has been growing and thus a new textile raw material has become available at home - alpaca wool.

At the moment, no rational concept exists of how to use this raw material. The Institute of Natural Fibres and Medicinal

Table 1. Designation of alpaca wool samples (for the ***Tables 2, 3, 4****); *) - designation of samples is associated with the marking of the animals from which the samples were taken.*

Item	Code of specimen*)	Colour	Length lock, mm
1	16 S.A.	dark beige	120
2	322 H.A.	dark bronze	85
3	0907/5361	dark bronze	90
4	5049 S.A.	white	200
5	318	grey	100
6	9081 S.A.	light bronze	150
7	85474	dark bronze	115
8	91 H.A.	dark bronze	85
9	H.A.	grey bronze	90
10	Pinta S.A.	beige / white	92
11	52 H.A.	black	75
12	19 H.A.	black	75
13	75 H.A.	black	80
14	18 S.A.	light bronze	110
15	606 S.A.	white	115

__Table 2.__ Mechanical and physical properties of alpaca wool fibres and results of alpaca fibre diameter measurements by Laser-Scan (LS) and Scanning Electron Microscopy (SEM).

Item	Fibre length (L)		Breaking strength (S)		Elongation at break		Linear density		Tenacity	Fibre diameter measurements by			
										LS		SEM	
	mm	V_L, %	cN	V_S,%	%	V_e, %	tex	V_m, %	cN/tex	µm	Vd, %	µm	Vd,%
1	110	8.0	6.3	53.5	40	30.4	0.392	5.79	16.07	20.6	26.2	20.0	24.5
2	75	23.1	6.7	38.2	45	14.0	0.476	6.47	14.07	20.8	22.1	21.0	23.0
3	80	10.2	7.4	40.8	46	19.1	0.629	5.79	11.76	24.0	34.6	25.2	28.6
4	185	16.5	8.0	40.1	50	33.9	0.652	6.06	12.27	24.3	19.8	25.6	21.2
5	70	28.5	10.2	42.1	38	16.3	0.660	4.50	15.45	24.4	22.5	25.8	23.6
6	98	12.0	10.3	42.2	51	42.3	0.731	8.50	14.09	24.7	27.1	26.0	25.7
7	105	8.0	11.9	35.4	46	22.6	0.736	7.21	16.17	26.1	23.0	26.7	24.3
8	80	18.5	12.3	34.7	48	15.5	0.752	4.36	16.36	26.7	24.7	27.2	25.2
9	85	11.4	12.4	49.6	51	28.1	0.773	4.07	16.04	28.4	19.7	27.8	21.8
10	87	14.0	13.4	50.9	50	14.5	0.814	7.96	16.46	29.1	29.6	29.0	24.3
11	65	12.5	13.6	52.7	51	18.3	0.908	6.97	14.98	29.3	24.2	29.2	23.9
12	70	12.8	13.8	45.6	38	41.1	1.000	6.48	13.80	30.1	22.3	31.0	24.1
13	75	10.8	13.8	45.7	38	45.3	1.060	7.99	13.02	32.5	17.2	33.7	18.5
14	100	10.6	14.8	37.2	45	19.5	1.160	6.48	12.76	35.1	23.1	34.0	22.8
15	110	9.8	12.9	43.4	40	24.6	1.280	6.36	10.08	35.4	24.3	35.0	23.3
Average	**93**		**11.2**		**45**		**0.802**		**14.23**	**27.4**		**27.8**	

Plants (INF&MP) is presently trying to solve the problem of scouring alpaca wool [5]. Knowledge of the fibre structure and its physical and mechanical properties is necessary for the elaboration of the concept of how to apply alpaca wool in textile products.

The problem of breeding alpacas, its wool and properties, the wool structure and its processing is quite new in Poland. On this subject, except for a study on breeding alpacas [1] and general Internet information about alpacas [2 - 4], there are no scientific publications in Poland.

The development of breeding alpacas affects the profitability of farming as well as the high quality and functional qualities of wool. For comparison, in Poland, washed sheep wool costs 3.5 - 4.7 Euro/kg, while the price of alpaca wool is 35 - 50 Euro/kg. The price of one Polish merino ranges from 50 - 60 Euro, while the price of one alpacas is around 1400 - 1800 Euro. Notwithstanding the high price of alpaca animals and wool, great demand exists in Poland for this new raw material because of its high quality and exotic fame. Currently in Poland there are five farms, the largest of which consists of 120 alpacas, and the total number of all alpacas bred in the country is about 600 pieces.

The aim of this study was to cognition the structure of external and internal alpaca fibres from Polish breeding and explore the basic physical and mechanical parameters thereof .

Test materials and methods

Wool fibres from Polish alpacas were the material studied. The studies were made for 15 fibre samples taken from various animals from a herd of 120 alpacas. All samples were collected in May with a one-year shearing. The places of sampling were the mid-dorsal parts of the animals.

The linear density, density, fibre length, strength, elongation at break, diameter as well as the external and internal fibre structure were investigated. Measurements of the linear density of fibres in

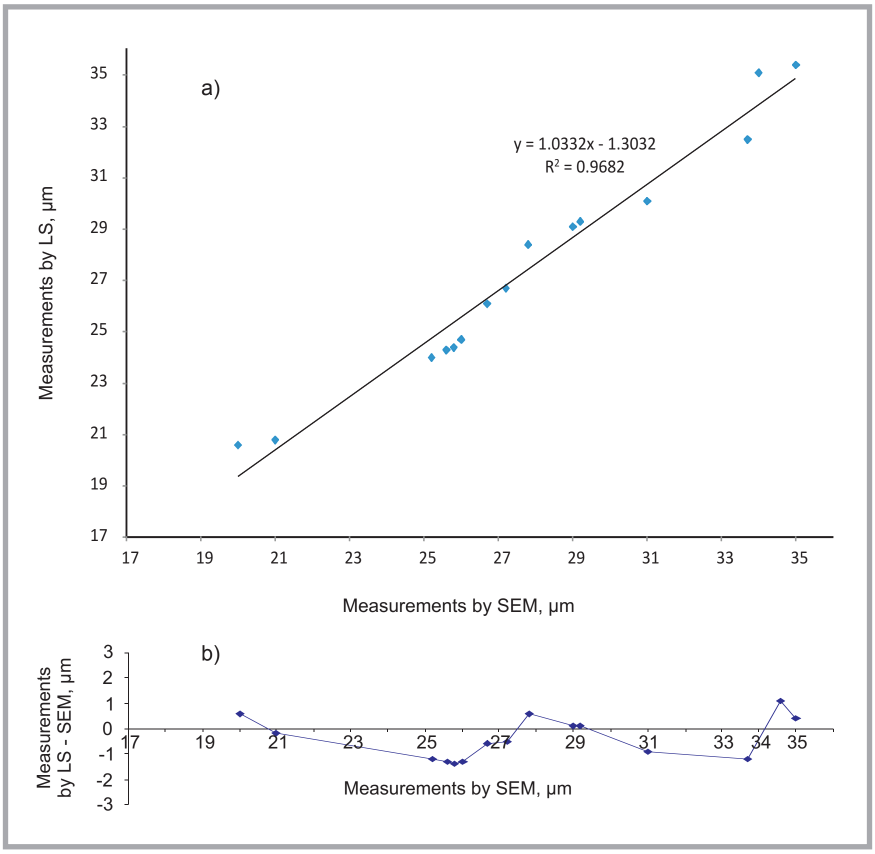

__Figure 1.__ a) Interrelationship between the results of alpaca fibre diameter measurements by Laser-Scan (LS) and Scanning Electron Microscopy (SEM) (R=0.984) and b) differences between Laser-Scan (LS) and Scanning Electron Microscopy (SEM) measurements of alpaca fibre diameter.

__Table 3.__ Results of the tests of alpaca fibre density; d - diameter obtained according to LS (Table 2).*

Item	Code of specimen according to Table 1	d*, μm	Real density ρ, g/cm³	Seeming density ρ, g/cm³
1	1 (16 S.A.)	20.6	1.301	1.282
2	2 (32 H.A.)	20.8	1.318	1.286
3	4 (5049 S.A.)	24.3	1.318	1.289
4	7 (85474)	26.1	1.312	1.290
5	10 (Pinta S.A.)	29.1	1.295	1.280
6	12 (19 H.A.)	30.1	1.318	1.298
7	15 (606 S.A.)	35.1	1.300	1.286
	Average:	**26.6**	**1.309**	**1.288**

tex were assessed according to Polish Standard PN-ISO 1973:1997. Special attention was given to measuring the fibre diameter as that of alpaca wool fibres is a very important parameter characterising the alpaca breed. Therefore the alpaca fibre diameter was tested with three methods; a laser method - Laser-Scan (LS), a micro projection method – using a projection microscope- Lanameter (PM), and a method using an electron scanning microscope (SEM).

All the tests were performed according to ISO standards.

To asses the internal and external structure, microscope tests were performed using a FEI NOVA NANOSEM 230 and JSM-5200 LV scanning microscope.

The fibre density was tested by the gradient column method at 25 °C. The gradient column was filled with a mixture of two liquids: toluene and carbon tetrachloride. The immersion liquid density range in the column was 1.20 - 1.40 g/cm³. Before measurement, the samples were dried and de-aerated in a vacuum for 5 hours. The samples were then flooded with the immersion liquid with a density of 1.20 g/cm³ and placed into the gradient column. For determination of the actual location of the density, the samples' po-

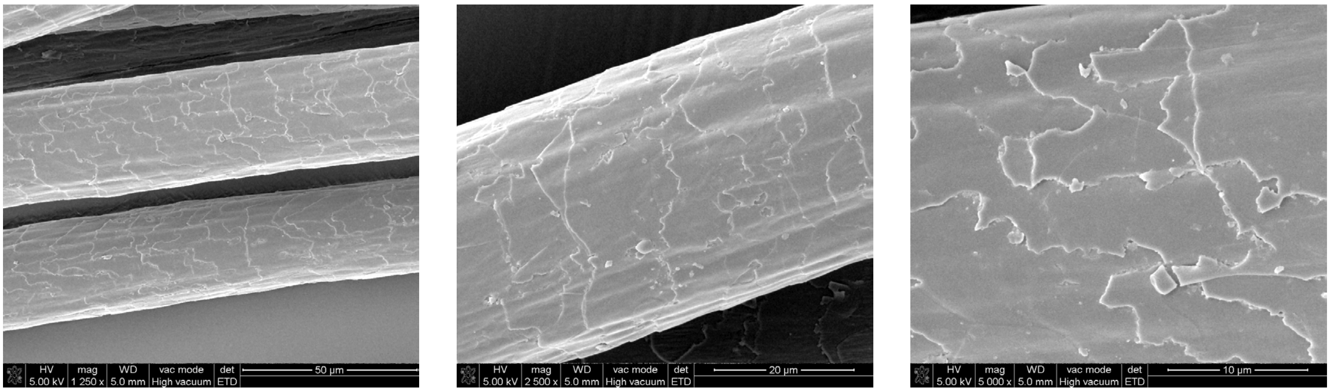

***Figure 2.** Photo fibres surface alpaca wool (Pinta S.A.-beige/white diameter 29.1 μm)*

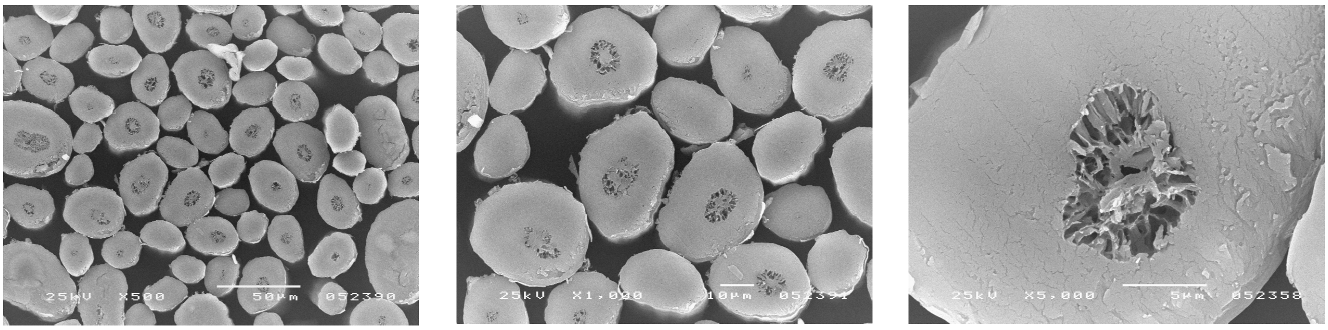

***Figure 3.** Photo SEM cross sections fibres alpaca wool (Pinta S.A.- beige/white diameter 29.1 μm)*

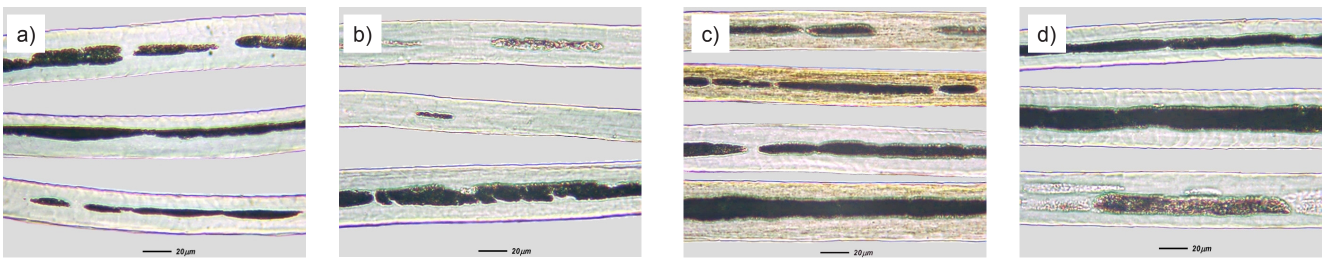

***Figure 4.** Photos of longitudinal view of alpaca fibres; a) 3 - 0907/5361 dark bronze, d = 24.0 μm, b) 4 - 5049 S.A. white d = 24.3 μm, c) 10 - Pinta S.A. beige/white, d = 29.1 μm, d) 15 - 606 S.A. white d = 35.4 μm.*

sition and standard floats in the column were read after 24 hours.

For determination of the apparent density, the following location of the samples was read in time. The distribution curve of the density of the liquid was plotted as a function of the column height, and on the basis of this relationship the density of the fibre being tested was established. Six series of tests were performed for each variant.

Designations of the samples, including the symbol of the sample, colour and length of wool fibres in the lock are presented in ***Table 1*** (see page 8).

Test results

Results of the physical and mechanical tests are presented in ***Table 2*** (see page 9).

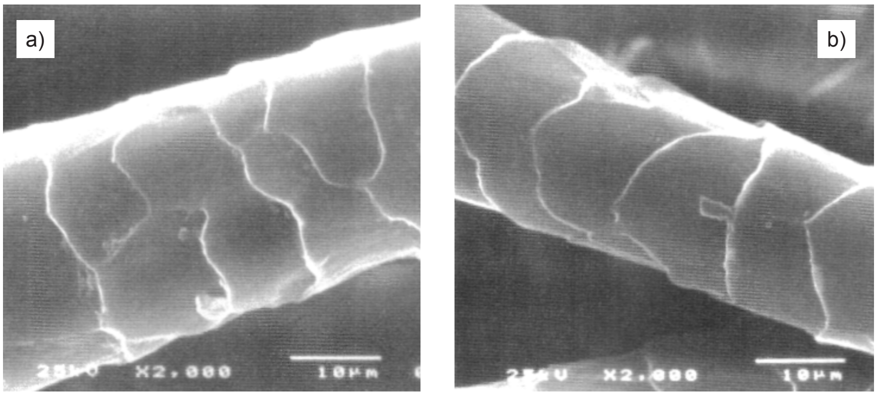

Figure 6. *Photo of the surface of merino sheep wool fibres (a - Polish, b - Australian).*

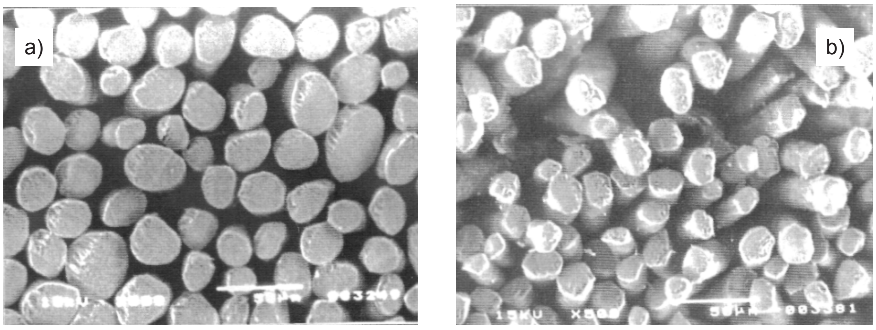

Figure 7. *SEM photo of cross sections of merino sheep wool (a - Polish, b - Australian).*

Results of the alpaca fibre diameter are shown in ***Table 2*** and in ***Figures 1*** (see page 9). ***Table 2*** does not provide the fibre diameters measured by optical microscopy due to the significant divergence of results in relation to the method of laser LS and SEM. Based on the diameter results obtained using the two methods, the correlation coefficient was calculated for the laser and scanning (LS-PM) methods. The interrelationship of results of the diameters for alpaca fibres from the above methods is shown in ***Figure 1***. The interdependence of the results of fibre diameters for the laser method (LS) and scanning method (SEM) is shown in ***Figure 1***. The correlation coefficient calculated for these methods is high, amounting to 0.988. The absolute differences between the results of the fibre diameters measured, occurring between the methods applied, are shown in **Figure 1.b**. The results of the tests of alpaca fibre density for seven characteristic samples selected (according to the designation from ***Table 1***) are shown in ***Table 3***.

Results of the evaluation of fibre surfaces, cross-sections and longitudinal views are shown as photos in ***Figures 2 - 4***.

Figures 5 & ***6*** are presented for comparison of the surface and cross sections of alpaca wool with sheep's wool. These figures present the wool of Australian and Polish merinosheeps.

Analysis of the results

From the results of physical and mechanical fibre property tests (***Table 2***), one can see that in various samples (taken from various animals)the alpaca fibres differ in length, linear density, strength and elongation at break. The unit strength values of alpaca wool, expressed as the tenacity, are close to that of sheep's wool [10]. The elongations at break of alpaca fibres are about 10% higher than those of fibres of sheep's wool.

The higher spreads of the breaking strength and elongation of alpaca wool compared with sheep's wool are a result of the internal structure of these fibres.

In alpaca fibres there are channels of different shape (variable width and length). The results of diameter tests (***Table 2***) also show that there is a great difference in the fibre diameter (20 - 35 μm.) of samples from one herd. On the basis of the alpaca fibre diameters (***Table 2*** and ***Figure 1.b***), it can be seen that the laser method yields diameter results only about 0.4 μm smaller than from the scanning method (SEM).

An analysis of the fibre surface, cross sections and longitudinal views, shown in ***Figures 2 - 4***, indicate that alpaca fibres differ a lot from wool fibres, presented in ***Figures 5 - 6***. The alpaca fibre surface also has scales, but their shape and character are different - they are smaller and more delicate than those of sheep wool fibres. Moreover the cross section of alpaca fibres is not as round as that of sheep wool fibres, and channels with a core type structure are observed in the fibre center, making alpaca fibre lighter than sheep wool fibre. The longitudinal views of the fibre clearly show the internal structure, displaying large closed air filled channels. This specific internal structure is mostly responsible for the high thermal quality of alpaca wool.

The results of measurements of alpaca fibre density for the seven samples of different diameter (***Table 3***) indicate a slight variation in the results. The values of the density of fibres in the samples studied vary in the range 1.296 - 1.318 g/cm^3. The average density of alpaca fibre is 1.309 g/cm^3 and the density is smaller than that of sheep wool fibre in general, which is equal to 1.32 g/cm^3. This difference is caused by the results from the different internal structures of alpaca and sheep fibres (compare ***Figure 3*** with ***Figure 6***).

The lower real density of real alpaca wool compared with sheep's wool confirms this.

Knowledge of the real density of the fibres - ρ in g/cm³ and their diameter - d in μm makes it possible to determine the fibre linear density T_t in tex:

$$T_t = \pi/4 \cdot d^2 \cdot \rho \cdot 10^{-3} = $$
$$= 0.7854 \cdot 10^{-3} \cdot d^2 \cdot \rho$$

Summing up

The results of studies of the external and internal structure of alpaca fibre allow to state that the structure of alpaca fibre differs a lot from that of sheep wool fibres: The external surface of alpaca fibres is more delicate with smaller and less pronounced scales. Moreover the cross sections are mostly oval in shape with a clearly defined channel of core structure.

The real density of the fibres of alpaca wool is lower than that of sheep wool fibres.

The physical and mechanical properties, linear density, strength, tenacity, elongation at break, length and diameter of alpaca fibre are varied in particular samples, the reason for which is uncontrolled herd breeding.

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