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Investigation of the dyeing characteristics of alpaca fibers (Huacaya and Suri) in comparison with wool

Rıza Atav[1] **and Fatih Türkmen**[2]

Abstract
Luxury fibers have great importance in the field of high added value fabric production, but the studies related to these fibers are very limited. One of these luxury proteinous fibers is alpaca wool. In this study, dyeing characteristics (dye-uptake speed, color efficiency and nuance of color, fastness properties, etc.) of alpaca fibers (Huacaya and Suri) were investigated by taking sheep wool as a reference. Furthermore, analysis such as scanning electron microscopy, energy dispersive X-ray and Fourier-transform infrared spectroscopy was also carried out. According to the experimental results it was found that both dye-uptake speed and amount was in the range of sheep > Suri alpaca > Huacaya alpaca for milling acid dye. Furthermore, when their fastness properties were compared with sheep wool, it could be said that there was no difference for washing and perspiration fastness, while rubbing and light fastness of alpaca fibers were lower than sheep wool.

Keywords
alpaca, wool, dye-uptake, color, fastness

Introduction

South American camelids occupy a very small niche in the world textile fiber market. The total production represents only 0.1% of worldwide production of animal fibers. Among domestic camelids, alpaca is the best for fiber production, being characterized by homogeneously fine, long and soft fleeces.[1] Alpacas are indigenous to the Andean highlands of South America. There are approximately 3.5 million alpacas in the world and most of them (~3.0 million) are located in Peru, while the majority of the remainder lives in Chile and Bolivia.[2] Compared with the wool industry which produces 2 million tons annually, the alpaca industry is very small with 4000 tons annual fiber production.[3] Average greasy hair prices in 2000 were US$2–10/kg.[4]

There are two types of alpaca: Huacaya and the Suri. Huacaya alpaca makes up more than 90% of the total alpaca population. They are bigger animals than Suri alpacas and have short curly hair. Suri alpaca fiber is generally finer, longer, softer and more lustrous than Huacaya alpaca and it has no crimp.[5] Alpaca fibers usually have a larger diameter than wool, customarily with 28–67% medullation. The average diameter is around 26 μm and the average staple length 100 mm.[6]

The most valued attribute of alpaca fiber is its handle, or how it feels to the touch: creamy, silky, and soft. Alpaca is also valued because it is lustrous, extremely strong and very warm (seven times warmer than wool thanks to microscopic pockets within the fibers that trap air).[3] Those who wear alpaca garments choose them because of their thermal qualities and resistant features of the fiber, as well as some other attributes such as their impermeability and anti-inflammability.[7] Alpaca's principal end-uses are in knitwear and lightweight suits. The major consumer markets are

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[1]Department of Textile Engineering, Namık Kemal University, Corlu, Tekirdağ, Turkey
[2]Özen Textiles, Dyeing and Finishing Enterprises Inc., Çerkezköy, Tekirdağ, Turkey

Corresponding author:
Rıza Atav, Department of Textile Engineering, Namık Kemal University, 59860, Çorlu-Tekirdağ, Turkey.
Email: ratav@nku.edu.tr

the USA, Japan, and Italy.[4] To maximize its uses, alpaca is commonly blended with other fibers, especially wool.[3]

As companion animals, alpacas are bred in a very large variety of colors.[8] This may provide a natural alternative to dyed fibers. However, textile manufacturers pay a premium for white or non-colored alpaca fibers,[9] because it is possible to dye these fibers into desired colors. As alpaca fibers are also protein based, their dyeing characteristics are similar to wool. For this reason generally same receipts are applied to alpaca fibers. However, it is important to know the dyeability differences between alpaca and sheep wool fibers in order to make suitable adjustments in dyeing receipts. When the literature is investigated, it is seen that most of the studies related to alpaca fibers concentrated on the investigation of fiber characteristics[1,2,6–8,10–14] and bleaching of pigmented fibers.[15–17] Even though in the literature there are some studies about dyeing properties of alpaca fibers, to the best of the authors' knowledge, there are no studies which compare the dyeability of Huacaya and Suri alpaca fibers with sheep wool.

In this study, dyeing characteristics (dye-uptake speed, color efficiency and nuance of color, fastness properties, etc.) of alpaca fibers (Huacaya and Suri) were investigated by taking sheep wool as a reference.

Materials and method

In the experiments, two different scoured alpaca fibers (from Huacaya and Suri varieties), and scoured merino sheep wool were used. Huacaya and Suri alpaca fibers were supplied from Alpacas de la Tierruca, Spain. Merino sheep wool was supplied from Yunsa, Inc., Turkey. All fibers used in the experiments were white in color. The fiber strength and elongation at break, as well as the fiber diameter were measured by using a single-fiber tensile tester (Prowhite) and optical fiber diameter analyzer (OFDA) respectively. On the other hand, alkali solubility values of fibers were determined according to the IWTO-4-60 test method. Results of these tests are listed in Table 1.

Furthermore CIEL*a*b* values and whiteness degrees of fibers were also measured and results were given in Table 2.

All experiments were carried out by using a milling acid dye: Telon Blue M-RLW (C.I. Acid Blue 204) which was kindly supplied by Dystar. Pure water was used for preparing dyeing liquors and liquor-to-goods ratio was 30:1.

Table 1. Physical properties and alkali solubility values of fibers used in experiments

Fiber	Diameter (μm)	Strength (CN)	Elongation (%)	Alkali solubility (%)
Huacaya alpaca	25	10.01	41.89	8.13
Suri alpaca	26.5	10.16	31.36	7.95
Sheep wool	25.5	9.04	27.81	11.36

Table 2. CIEL*a*b* values and whiteness degrees of fibers used in experiments

Fiber	L*	a*	b*	Whiteness degree (Berger)
Huacaya alpaca	81.06	–0.43	7.57	30.95
Suri alpaca	83.83	0.21	12.25	17.68
Sheep wool	86.52	0.76	12.49	16.47

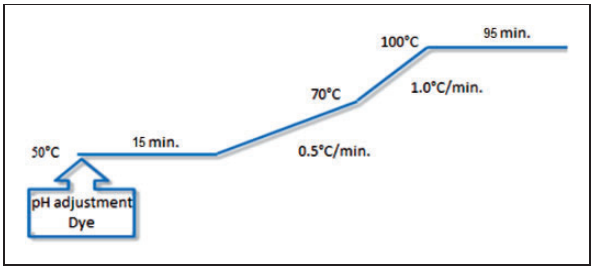

Figure 1. Dyeing graph used in the experiments.

Dyeing procedure

Dyeings were carried out according to the graph given in Figure 1. Prior to dyeing, the dyebath pH was adjusted to 5.5 with acetic acid and then dye was added. Dyeing depth was 3% owf. After dyeing, the liquor was cooled down and the fibers were taken out. Then dyed samples were rinsed and dried. All experiments were carried out in Termal HT type dyeing machine with 12 shaking baths and a temperature and time control unit.

In order to avoid fibers affecting each other's dye-uptake property due to the competitiveness, fibers were dyed in separate dyebaths. During the dyeing procedure, for each fiber 12 equivalent dyeing liquors were prepared and then every 15 minutes one of them was taken out. Then the absorbance values of these samples were measured with Aquamate UV-VIS spectrophotometer at 630 nm which was the wavelength of maximum absorption and then their relative (%) absorbance values were calculated by taking the absorbance value of initial dyeing liquor as 100. Afterwards dye-uptake (%) values for each

15 minutes of dyeing were calculated with the aid of the formula

$$\text{Dye-uptake (\%)} = [100 - \text{Relative(\%) absorbance value}]$$

By using these values, every 15 minutes of dyeing, dye-uptake curves of fibers versus dyeing time were drawn.

Color measurements

The reflectance (R) and CIE L*, a*, b*, C*, h values of the dyed samples were determined with a Datacolor SF-600 Plus C-T reflectance spectrophotometer with illumination/observer conditions set at D65/10° at 630 nm which was the wavelength of maximum absorption. Then the color efficiency expressed as K/S was calculated from Kubelka–Munk equation as shown below:

$$\frac{K}{S} = (1 - R)^2/2 * R$$

where R is the reflectance of the dyed sample, K is the absorption coefficient and S is the scattering coefficient. For color measurements, three samples were tested to compute the average value.

Fastness properties

The color fastness to washing, rubbing, perspiration and light was carried out according to ISO 105-C06, ISO 105-X12, ISO 105-E04, and ISO 105-B02 standard test methods, respectively.

Alkali solubility

Test method IWTO-4-60 was followed for alkali solubility test (0.1 N NaOH, 65°C, 1 h). It was calculated as a percentage of the original mass, according to

$$\text{Alkali solubility (\%)} = M_1 - M_2/M_1 * 100$$

where M_1 is the mass of the oven-dried sample before sodium hydroxide treatment and M_2 is the mass of the oven-dried sample after sodium hydroxide treatment.

IR spectroscopic analysis

In order to determine the differences in chemical structures, especially disulphide content, of the fibers used in experiments, fibers were subjected to Fourier-transform infrared (FTIR) analysis. FTIR spectrophotometer, model Vertex 70 ATR, made by Buriker was used over the range 500–4000 cm^{-1}.

Microscopic analysis

In order to determine the cuticular scale height and number of the cuticular scales per 100 μm of fiber length, scanning electron microscopy (SEM) analysis was carried out. Furthermore, the energy dispersive X-ray (EDX) analysis was also realized to obtain the elemental composition of each fiber. A Quanta FEG 250 scanning electron microscope (FEI, the Netherlands) was employed for imaging and obtaining the EDX spectrum of fiber samples at 5000 × magnification.

Results and discussion

Results related to the comparison of dye-uptake rates of alpaca and wool fibers

Figure 2 shows the dye-uptake curves of Huacaya alpaca, Suri alpaca and sheep wool fibers during dyeing with C.I. Acid Blue 204 dye.

According to the results given in Figure 2, it can be said that dye-uptake speed (from the gradients) was in the range of sheep wool > Suri alpaca > Huacaya alpaca especially at the initial stage of dyeing. As is commonly known, one of the most important parameters affecting the dye-uptake speed is fiber fineness. For this reason, in order to prohibit dye-uptake differences due to the differences in fiber fineness, fibers having similar diameters were used in this study. Diameters of Huacaya alpaca, Suri alpaca and sheep wool were 25, 26.5 and 25.5 μm, respectively, as given in Table 2. As there is no significant difference among fibers by means of diameter, the reason of dye-uptake difference should be due to the difference in the fiber polymer's molecular structure.

One of the parameters affecting the rate of dye-uptake of wool fibers is the cuticle layer. The cuticle cells comprise about 10% of the mass of the whole fiber and overlap each other with the exposed edges pointing towards the tip of the fiber. The structure of the cuticle can be subdivided into three regions: an enzyme-resistant exocuticle, an enzyme-digestible endocuticle and a thin epicuticle. The epicuticle of proteinous fibers is strongly hydrophobic in character and forms a resistant barrier to the penetration of dyes: the so-called surface barrier effect.[18] For this reason differences in the fiber surface properties such as the cuticular scale height and scale frequency probably account for the great differences in the ease of penetration of dyes. In order to determine the cuticular scale height and number of the cuticular scales per 100 μm, SEM analysis was carried out. Results are given in Figure 3.

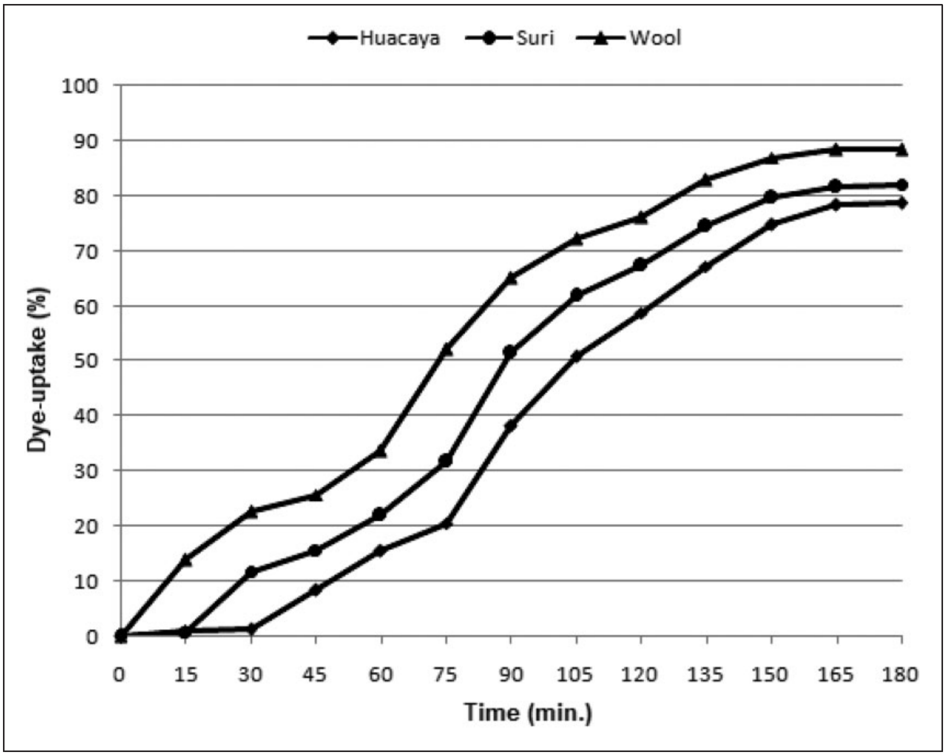

Figure 2. Dye-uptake curves of Huacaya alpaca, Suri alpaca and wool fibers during dyeing with C.I. Acid Blue 204.

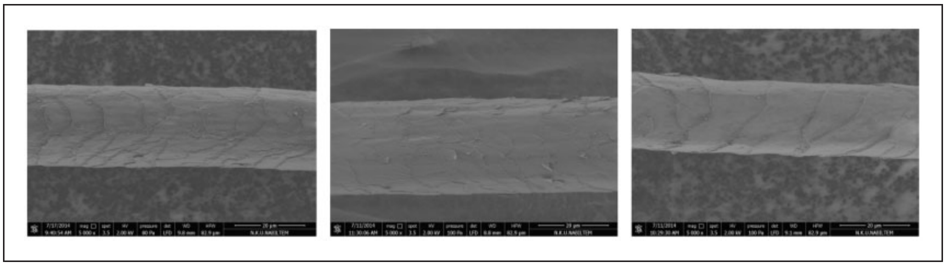

Figure 3. SEM photographs of Huacaya alpaca (on the left), Suri alpaca (in the middle) and Sheep wool (on the right) fibers with 5000× enlargement.

As can be seen in Figure 3, fiber scales in both the Huacaya and Suri alpaca are thinner and denser than the sheep wool. As Liu et al. stated in their study, the cuticle of wool is composed of perfectly defined scale-type cells with jutting out edges, however, the cuticle in the alpaca fibers is formed by poorly developed elongated and flattened cells.[19] Scale height and scale frequency of fibers used in experiments are given in Table 3.

Table 3. Cuticular scale height and number of the cuticular scales per 100 μm of fibers used in the experiments

	Scale height (μm)	Number of the cuticular scales per 100 μm of fiber length
Huacaya alpaca	0.51	9.08
Suri alpaca	0.48	7.75
Sheep wool	0.62	6.65

Measurements on fiber scale height and scale frequency indicate that Huacaya and Suri alpaca fibers have more scale ends and a lower scale height than wool. The scale height of Huacaya and Suri alpaca fibers are 0.51 and 0.48 μm, respectively, while that of wool fiber is 0.65 μm. On the other hand, the number of the cuticle scales per 100 μm length of fiber of sheep wool is approximately 7, while that of Huacaya and Suri alpaca fibers are approximately 9 and 8, respectively. Results related to the Huacaya and Suri alpacas are consistent with reports of Valbonesi et al.[1]

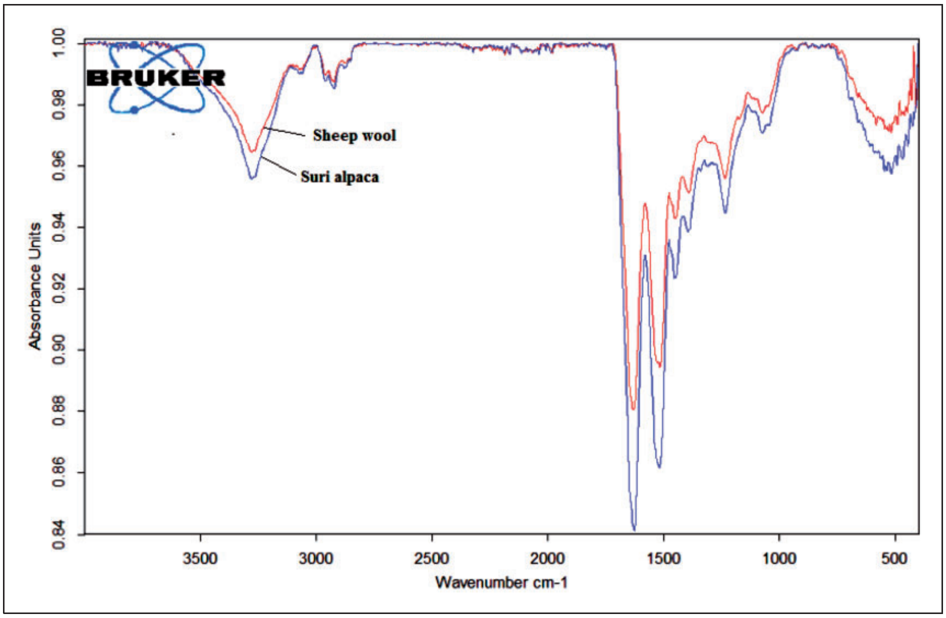

Figure 4. FTIR spectra of Suri alpaca and sheep wool.

According to these results, the scale height of fibers can be ordered as sheep wool > Huacaya alpaca > Suri alpaca. On the other hand, scale frequency of fibers decreases in the range of Huacaya alpaca > Suri alpaca > sheep wool. These results well explain the difference in dye-uptake rate between Huacaya and Suri alpacas. The lower scale height and scale frequency for Suri alpaca fibers, means that barrier to the penetration of dyes is weaker for Suri alpaca compared with Huacaya alpaca. As a result, Suri alpaca can exhaust dyes from the liquor more rapidly. Although fiber scale height and frequency results explain the dye-uptake difference between Huacaya and Suri alpaca fibers, it is difficult to explain why sheep wool uptakes dye more rapidly compared with alpaca fibers only on the basis of fiber scale height and frequency results. Sheep wool has lower scale frequency, but on the other hand it has higher scale height compared with alpaca fibers.

In order to explain the difference in dye-uptake speed of Suri alpaca and sheep wool fibers FTIR analysis was carried out. In this way it was possible to demonstrate the differences in their chemical structures. The FTIR spectrum consists of many bands. The intensity of each signal depends on the concentration of the functional group. The FTIR-ATR technique can analyze to a depth of 500 nm which is good enough to detect the surface chemical components of the wool fiber. Therefore, the FTIR-ATR technique offers both qualitative and quantitative methods for measuring composition of the wool surface.[20] FTIR spectra of Suri alpaca and sheep wool fibers are given in Figure 4.

In the FTIR spectrum, the band at 500–590 cm^{-1} was attributed to the disulphide bonds. When Figure 4 is investigated, it is understood that Suri alpaca fibers contain more disulphide bonds compared with sheep wool. As is generally known, disulphide bonds, in other words cystine linkages, increases the surface barrier of the fiber. The disulphide bonds of cystine form crosslinks, either between different protein chains (the inter-chain bonds), or between different parts of the same protein chain. The cystine inter-chain crosslinks are responsible for the greater stability and lower solubility of keratin, compared with most proteins.[21] Alkali solubility values of fibers given in Table 1 also confirm FTIR results. As can be seen in Table 1, Suri alpaca fibers have lower alkali solubility than sheep wool fibers. Another way to show the difference in disulphide bond amount in the fiber is the measurement of sulphur content. Because, except for a small amount of the amino acid methionine, the sulphur content of wool occurs in the form of cystine.[21] In order to determine the sulphur content of Suri alpaca and sheep wool fibers, SEM/EDX analysis was carried out and results are given in Figure 5. The elemental compositions of these fibers are listed in Table 4.

As can be seen in Figures 5 and 6, Suri alpaca fibers have higher sulphur content compared with sheep wool. From Table 4, it is understood that sulphur content of Suri alpaca is 5.41 wt%, while sheep wool is 2.19 wt%. These results are consistent with the FTIR analysis. Hunter and Mandela also stated that the cystine amino acid content of Suri alpaca was higher compared with sheep wool. In their study, cystine amino acid content of Suri alpaca and sheep wool were found to

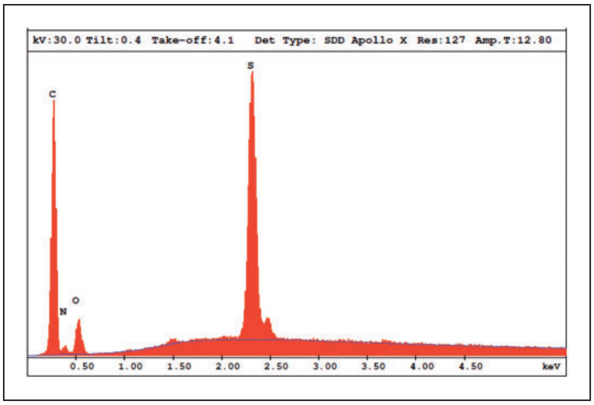

Figure 5. SEM/EDX analysis of Huacaya alpaca.

Table 4. Elemental compositions of Huacaya alpaca, Suri alpaca and sheep wool fibers (Wt, weight; At, atomic)

	Huacaya alpaca		Suri alpaca		Sheep wool	
Element	Wt (%)	At (%)	Wt (%)	At (%)	Wt (%)	At (%)
C	70.20	76.13	76.03	82.21	69.38	74.87
N	10.58	9.84	4.62	4.29	10.53	9.74
O	15.25	12.42	13.94	11.31	17.90	14.50
S	3.97	1.61	5.41	2.19	2.19	0.89

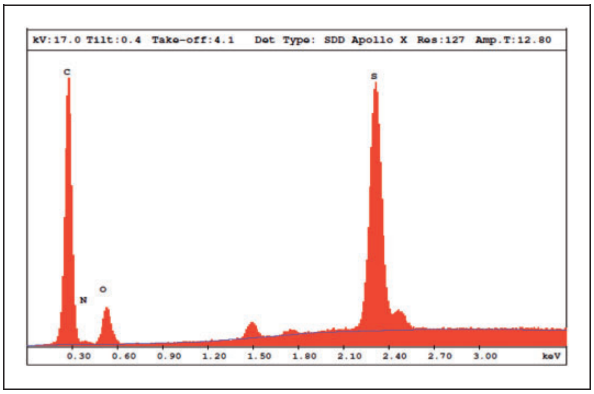

Figure 6. SEM/EDX analysis of Suri alpaca.

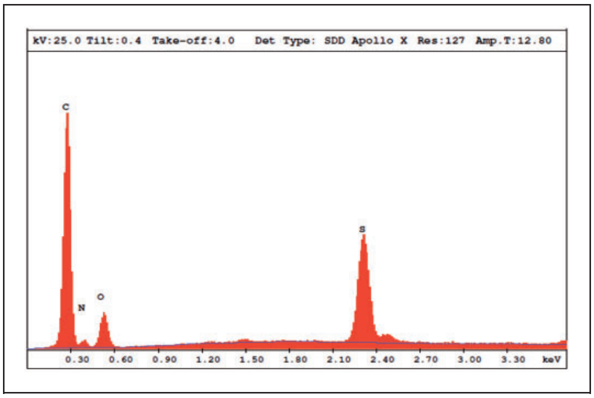

Figure 7. SEM/EDX analysis of sheep wool.

be 1250 and 900 mmol/kg, respectively.[22] All these results explain why the dye-uptake rate of Suri alpaca is lower than sheep wool at same dyeing conditions.

As a summary, it is possible to say that the difference in dye-uptake speed of alpaca and sheep wool fibers are attributable to their different sulphur content. As Huacaya and Suri alpaca fibers have greater amount (%) of sulphur compared with sheep wool (Figures 5–7 and Table 4), their dye-uptake speed is lower. On the other hand, difference between two alpaca varieties can be explained by differences in their scale height and scale frequency. As scale height and scale frequency is lower in Suri alpaca fibers, they can exhaust dyes from the dyebath more rapidly than Huacaya alpaca fibers.

Results related to the comparison of equilibrium dye-uptake amounts of alpaca and wool fibers

According to the results given in Figure 2, it can be said that equilibrium dye-uptake is in the range of sheep wool > Suri alpaca > Huacaya alpaca. As generally known anionic dyes such as milling acid dyes, form electrostatic forces with the positively charged protonated amino groups ($-^{+}NH_3$) of protein fibers. Furthermore van der Waals forces and hydrophobic interactions also involved between these dyes and protein fibers. As the nitrogen (%) content in fiber would be an indication of the molar amount of amino ($-NH_2$) in fiber, this value would be useful in explaining differences in dye-uptake amounts. As can be seen in Table 4, N (%) content of Suri alpaca fibers is lower than sheep wool. These results explain the difference in dye-uptake capacity of Suri alpaca and sheep wool fibers. However, Huacaya fiber has the lowest potential of equilibrium dye-uptake, although its nitrogen content is similar to wool. This could be explained when their chemical structure is taken into consideration.

Wool fiber exhibits a typical core–shell structure consisting of an inner protein core, the cortex which is covered by overlapping cuticle cells with scale edges pointing in the direction of the fiber tip.[23] The cortex layer consists of two sections, ortho and para. Bilateral segmentation of ortho- and paracortical cells predominates in wool fibers of diameters up to 25 µm. The orthocortex has a more open structure compared with the paracortex therefore it is more accessible for dyes.[24] For this reason the cortex, especially the orthocortex, content of the fiber has great importance on dye-uptake behavior of the fiber. Merino fiber is basically a solid fiber whereas Huacaya alpaca fiber broader than

20–22 μm has an internal medulla cell, which increases in size with the fiber diameter.[25] On the other hand, Suri fiber contains less medullation than Huacaya[26] or in some cases it does not contain medullation.[6] By taking into consideration that the fiber containing medullation will have lower cortex content than the fiber having same diameter without medullation, it is possible to explain the reason of lower dye-uptake of Huacaya alpacas compared with Suri alpaca and sheep wool. As Huacaya alpaca fibers contain medullation, their cortex content is lower than Suri alpaca and sheep wool fibers, and hence they have less equilibrium dye-uptake amount.

Results related to the comparison of color and fastness properties of alpaca and wool fibers

After comparing the dye-uptake speed and amount of alpaca fibers with sheep wool, colors of dyed samples were investigated. Color efficiency values of dyed samples at same conditions are given in Figure 8.

As can be seen from the results given in Figure 8, color efficiency increases in the range of Huacaya alpaca < Suri alpaca < sheep wool. These results are parallel with equilibrium dye-uptake amounts.

CIEL*a*b* values of dyed samples were also measured and results are given in Table 5.

If L* values given in Table 5 are examined, it can be said that L* values decrease in the range of Huacaya alpaca > Suri alpaca > sheep wool. The L* value is the value of lightness–darkness and the decrease of L* value shows that the color gets darker. From this point of view, the results obtained are parallel with *K*/*S* values. On the other hand, in the range of Huacaya alpaca–Suri alpaca–sheep wool, a* values increase and b* values decrease, which means color nuance becomes reddish (in other words less greenish) and bluish (in other words less yellowish), respectively. The color nuance of the dyed sample is affected by the material's color prior to dyeing. For this reason both CIEL*a*b* values and whiteness degrees (Berger) of undyed fibers were measured and results are given in Table 2. As can be seen in Table 2, the main difference among the fibers exists in b* values. The b* values increase in the range of Huacaya alpaca < Suri alpaca < sheep wool, which means color gets yellowish. Also whiteness degrees are in accordance with these results. Sheep wool has the lowest whiteness degree, which means its color is more yellowish compared with alpaca fibers. While differences among Suri alpaca and sheep wool fibers were very small, they were evident in the case of Huacaya alpaca and Suri alpaca or sheep wool. From these results it is understood that results related to the b* values of dyed samples are not in accordance with undyed fibers' b* values. For this reason, it can be said that as wool fibers were dyed darker, yellowness of fiber's ground color could be covered in the case of sheep wool dyeing.

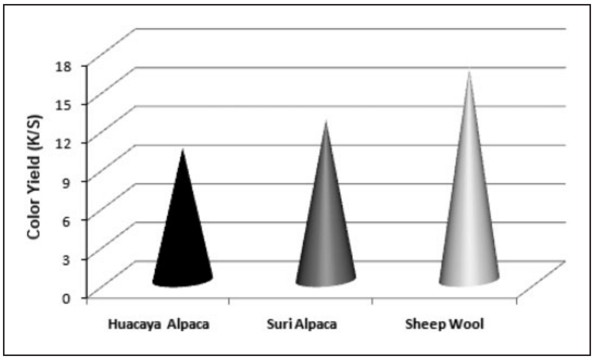

Figure 8. Color efficiency (*K*/*S*) values of fibers dyed with C.I. Acid Blue 204.

Table 5. CIEL*a*b* values of fibers dyed with C.I. Acid Blue 204

Fiber	L*	a*	b*	C*	h
Huacaya alpaca	39.88	0.40	–38.83	38.84	270.59
Suri alpaca	37.64	1.61	–39.90	39.93	272.31
Sheep wool	34.09	3.93	–40.94	41.13	275.49

These results reveal that in dyeing of Huacaya and Suri alpaca fibers not only the color depth, but also the color nuance will be different from sheep wool.

In a dyeing process another important parameter is fastness. For this reason, washing, rubbing, perspiration and light fastness tests of dyed samples were also carried out. Results are given in Tables 6 and 7.

In Tables 6 and 7, it is seen that high washing and perspiration fastness values are obtained in all three fibers. When fibers are compared among themselves, it can be said that there is no difference. In fact, when it is taken into consideration that the Huacaya and Suri alpaca fibers are dyed in lighter shades compared with sheep wool, it can be said that alpaca fibers dyed the same color depth would show lower resistance to washing and perspiration compared with sheep wool. Because, if a sample shows same wet fastness value with a sample dyed in darker shade, probably it will have lower wet fastness value when it is dyed the same color depth.

When Table 6 is investigated, it is understood that dry and wet rubbing fastness values of Huacaya and Suri alpaca fibers are lower than sheep wool. Taking into consideration that the Huacaya and Suri alpaca fibers gave lower rubbing fastness values even though they were dyed in lighter shades compared with sheep

Table 6. Washing, rubbing and light fastness values of fibers dyed with C.I. Acid Blue 204

	Washing fastness							Rubbing fastness		
Fiber	CA	CO	PA	PES	PAN	WO	Color change	Dry	Wet	Light fastness
Huacaya alpaca	5	5	4–5	5	5	5	5	4	3–4	6
Suri alpaca	5	5	4–5	5	5	5	5	4	3–4	6
Sheep wool	5	5	4–5	5	5	5	5	4–5	4	6–7

Table 7. Acidic and basic perspiration fastness values of fibers dyed with C.I. Acid Blue 204

		Perspiration fastness						
Fiber		CA	CO	PA	PES	PAN	WO	Color change
Huacaya alpaca	Acidic	4–5	4–5	4	5	5	4–5	4–5
	Basic	4–5	4	3–4	4–5	4–5	4	4
Suri alpaca	Acidic	4–5	4–5	4	5	5	4–5	4–5
	Basic	4–5	4	3–4	4–5	4–5	4	4
Sheep wool	Acidic	4–5	4–5	4	5	5	4–5	4–5
	Basic	4–5	4	3–4	4–5	4–5	4	4

wool, it can be said that rubbing fastness problem would be faced during dyeing of alpaca fibers especially in dark shades.

Light fastness mainly depends on a dye chromophore and dyeing depth. For this reason high light fastness values of dyed samples could be attributed to chemical structures of dyes used in experiments. If light fastness values are compared among themselves, it can be said that the light fastness of Huacaya and Suri alpaca fibers are a little bit lower, because alpaca fibers are dyed lighter compared with sheep wool. As generally known, in lighter shades lower light fastness values are obtained compared with darker shades for a certain dye. Because the dye amount which is damaged by the effect of light is consistent and if dyeing shade is lighter, dye percentage which is damaged will be higher and hence the light fastness values will be lower.

Conclusion

Luxury fibers have great importance in the field of high added value fabric production. But the studies related to these fibers are very limited. One of these luxury proteinous fibers is alpaca. The aim of this study was to investigate the dyeing characteristics (dye-uptake speed, color efficiency and nuance of color, fastness properties, etc.) of alpaca fibers (Huacaya and Suri) in comparison with wool. According to the experimental results it can be said that both dye-uptake speed and amount are in the range of sheep wool > Suri alpaca > Huacaya alpaca for milling acid dye. Furthermore, in addition to the color efficiency, there is a difference in color nuance among the fibers. It can be said that color nuance becomes reddish and bluish in the range of Huacaya alpaca–Suri alpaca–sheep wool.

On the other hand, it was observed that washing, perspiration, rubbing and light fastness values obtained in all two specie of alpacas (namely Huacaya and Suri) with milling acid dye were high. When their fastness properties are compared with sheep wool, it can be said that there is no difference for washing and perspiration fastness, while rubbing and light fastness of Huacaya and Suri alpacas are lower than sheep wool.

It is thought that results related to the comparison of dyeing properties of alpaca fibers with sheep wool will give opinion on the possible results when alpaca/sheep wool fiber blends are dyed. As is known, it is common to use alpaca fibers by blending it with wool fibers with the aim of reducing costs and also improving processibility especially for yarn production. In this case, it is thought that it would be difficult to obtain uniform dyeing when alpaca/wool yarn or fabric (in which alpaca and wool yarns are used) is dyed. Although the use of reserving agents could compensate for dyeability differences of alpaca and sheep wool fibers, it is believed that the simplest solution of this problem is to dye these two components separately in loose stock or yarn form and then to produce yarn or fabric. In further studies some research on dyeing of alpaca/wool blends could be done in order to clarify these suggestions.

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