Elastic properties effect of nanoparticles-functionalized alpaca fibers by the photoacoustic method

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The textile industry is one of the essential branches of the economy of many countries globally, and the importance of wool is still immense. Peru is the largest exporter of alpaca and vicuña fiber, considered "natural super-fibers" due to their extraordinary properties. Such as resistance, elasticity, moisture insulation, more efficiency than others in heat exchange, hypoallergenic (without lanolin), and soft contact with the skin, as described by D. Jankowska et al. [1]. By functionalizing the natural fibers with metallic nanoparticles to make them antibacterial and metal oxides to make them superhydrophobic, the capacity of their natural properties will be increased, obtaining a hybrid fabric, as described by H. Memon et al. [2]. However, there is that corroborated if their properties physical- mechanicals no change. For that reason, in this work, we are in charge of evaluating the elastics properties of the alpaca fibers before and after being functionalized using the pulsed photoacoustic technique. These results are corroborated with the traction tests. This research will help some communities in Peru and worldwide that suffer from cold weather and lack water and electricity to clean their clothes. Furthermore, with the knowledge acquired during this research, it is possible to venture into the cotton textile area to translate the same study into sterile whites for hospital environments and sterile and disposable healing material.

Methods – In this work, eight colors of alpaca fibers were studied: white, light beige, medium beige, dark beige, dark brown, shiny dark brown, dark brown-black and black, and one vicuña: light brown, natural and functionalized with nanoparticles: Ag, Au, TiO_2, ZnO. First, the elastic constants of the fibers above were evaluated, following the respective procedure: 1) A cleaning protocol was used to preserve the fibers' natural properties. 2) An optical microscope with a 5Mp camera (Nikon Eclipse, 40x/0.65) was used to measure the diameter of the fibers because it is a necessary variable to calculate the modulus of elasticity. 3) An experimental photoacoustic (PA) arrangement was used for two geometries, that is, in the longitudinal (L) and transverse (T) directions of the fibers, as shown in Figure 1.

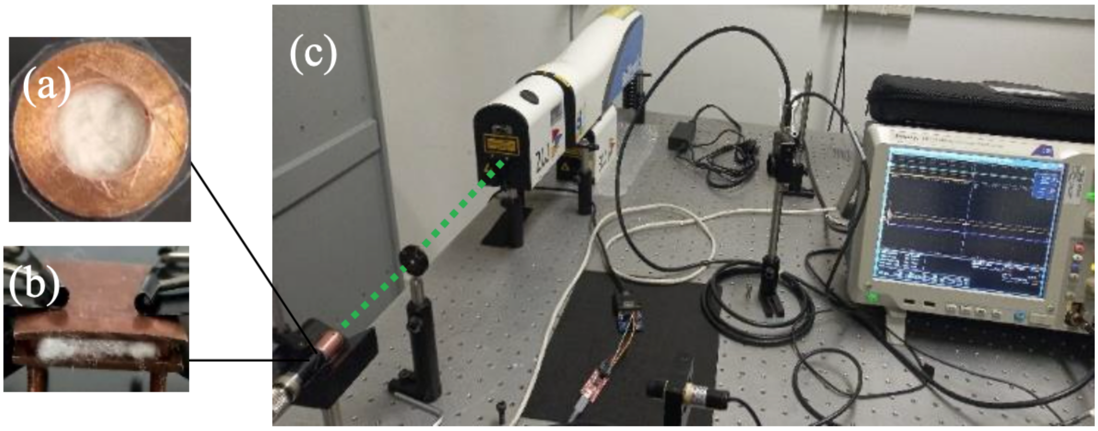

Fig. 1. (a, b) The sample-holders with white fibers in the longitudinal and transverse geometry, **(c)** Photoacoustic experimental setup used for all samples. Consisting of a Nd: YAG laser (λ = 532 nm, F = 10Hz, τ = 5ns, Fluence = 1.25 J/m), a sensor 3.5 MHz (Olympus Panametrics), a digital phosphor oscilloscope 2 GHz (Tektronix), and optical arrays.

4) To corroborate the elastic constants obtained by the two geometries of the PA method, they were compared with the tensile tests using a tensor grip A/TG (Stable Micro System).

Results – The arrival times of all the photoacoustic signals belonging to each color were obtained (eight colors of alpaca fibers and one color of vicuña fiber) using the two configurations(L and T). Measurements were made in triplicate for each color. Figure 2 shows the offset of the PA signal output for each interface that is added in the signal path, given the geometric arrangement shown in Figure 1a. The Young's Modulus or elasticity modulus was also obtained by analyzing the tensile tests for all the samples. Figure 2b shows the average value of Young's modulus of the white alpaca fiber.

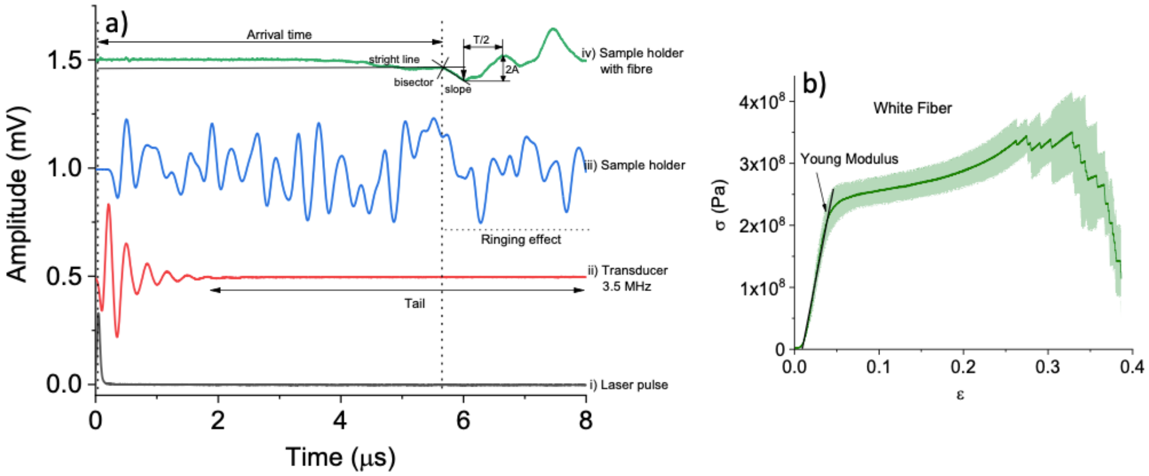

Fig. 2. (a) Arrival times of the PA signals in the L direction for each interface that is added in the signal's trajectory. The corresponding geometric arrangement is shown in Fig. 1a. (i) Laser pulse waveform; (ii) piezoelectric transducer output signal generated by the excitation of the laser pulse; (iii) PA signal generated by the sample holder, without sample, showing the ringing effect; and (iv) PA signal output with the sample fixed inside of the sample holder. **(b)** Average value of Young's modulus of white alpaca fiber obtained by analysis of tensile tests

Conclusions – The determination of the elastic constants in two directions using different geometric arrangements has been demonstrated, considering that the fibers behave as transversely isotropic materials. The properties and performance of nanoparticle fibers depend on the geometric attributes of the fibers, such as volume fraction, density, and size distribution. When another phase, such as metallic nanoparticles or semiconductor metal oxides, is included in the mixing solution, these particles are not evenly distributed within the long fiber, which changes its mechanical behavior. We find that depending on the concentration of the particles, they behave as defects or reinforcements.

References

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