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ELASTIC MODULI OF HUMAN AND ANIMAL KERATINISED TISSUE – THE HAIR

MOHAMMAD EHTESHAMUDDIN AZIZ, KALEEM AHMED JALEELI & ADEEL AHMED
Biophysics Research Laboratory, Department of Physics, Nizam College (Autonomous), Osmania University, Hyderabad, India.
e. mail: dr_adeelahmad@yahoo.com
aziz099@gmail.com

ABSTRACT

The paper deals with the elastic moduli of human and animal hair. Elastic moduli measured are Young's modulus (Y), bulk modulus (k), rigidity modulus (μ), and Poisson's ratio (σ). The technique employed for Young's modulus and rigidity modulus are Searle's method and Torsion pendulum method respectively. The present study shows significant variation in Young's modulus, bulk modulus, rigidity modulus, and Poisson's ratio for human and animal hair samples.

Key words – Human, Animal, Hair, Elastic constants, Searle's method, Torsional pendulum

1. INTRODUCTION

Microscopically viewing the tissue material and by applying to it the principles of mechanics, the mechanical properties and behavior of biological materials may be described. As far as the mechanical make-up is concerned, the components of the soft connecting tissues are the same, consisting of differently combined aggregates of elastic fibers.

Vertebrate body contains both soft and hard tissues to carry out life processes. Among the hard tissues hair is a derivative of the skin. The hard tissues are highly useful in protecting the body from the environmental influences. Biologists have developed several areas but no attention is paid to make investigations on physical properties of this tissue. However, the mechanical properties of hair were found by employing the techniques such as Searle's method and Tortional Pendulum.

Adeel Ahmad and coworkers did extensive work on elastic behavior of biological tissues, which include hard calcified animal tissues [1 - 7], soft animal tissues [8 - 9], and wood [10]. For the first time, from ultrasonic studies, they reported that blood is a viscoelastic fluid [11].

A perusal of literature reveals that no attention is paid to study the mechanical properties of animal and human hair, though they are abundantly available in nature. While investigating the elastic properties, the authors tried to establish the validity of simple laboratory techniques involved in the process. These basic techniques can be employed to evaluate the elastic constants in the absence of sophisticated expensive equipments.

2. Materials and Methods

The hair samples were obtained from animal (horse) and also from human (female). The thickness (t) of the hair samples was determined by using travelling microscope. Most of the hair samples were not perfectly circular in cross section. Hence, maximum care was taken in selection of the hair samples with circular cross-section by making microscopic observation.

To determine the young modulus of the hair, the elongation for a particular load was measured. For this purpose, special weights of 5 gm each for human hair and 25 gm each for animal hair and the weight hanger was designed with aluminum metal. The apparatus was prevented from air, which may otherwise result in oscillation of hair sample along with the load applied. The elongation (e) of the hair of length (l) and radius (r) was measured for different loads (M) using travelling microscope. A plot drawn between **M** and **e** for different samples is a straight line and reciprocal of its slope gives average value of **M/e.**

Young's modulus of the hair was determined by the relation,

$$Y = \frac{gl}{\pi r^2}\left(\frac{M}{e}\right)$$

where M: Mass applied (gm)

l: Length of hair sample (cm)

r: Radius of hair (cm)

e: Elongation of the hair (cm)

g: Acceleration due to gravity (cm/sec^2).

To determine rigidity modulus, a specially designed circular metallic disc for animal hair and plastic disc for human hair was suspended with the hair sample. The disc was made to oscillate radially, housing it in a glass casing, and the time period (T) was measured for different lengths (l) of the hair sample by using a stop watch which can measure the time upto 1 millisecond. A plot drawn between l and T^2 for different hair samples of radius 'r' is a straight line and reciprocal of the slope of which gives average value of l/T^2.

Rigidity modulus of hair samples was calculated using the relation

$$\mu = \frac{8\pi}{r^4}\left(\frac{MR^2}{2}\right)\left(\frac{l}{T^2}\right)$$

where M: Mass applied (gm)

R: Radius of the disc (cm)

r: Radius of hair (cm)

T: Time period (sec)

Then the Poisson's ratio will be

$$\sigma = \left(\frac{Y}{2\mu} - 1\right)$$

And, Bulk Modulus is given by

$$k = \frac{Y}{3(1-2\sigma)}$$

3. Results and Discussion

Table 1 reports the average values of Young's modulus, rigidity modulus, bulk modulus, and Poisson's ratio of Animal (Horse) and Human hair. The bulk modulus (k) and Poisson's ratio (σ) are the derived parameters of directly calculated parameters - Young's modulus (Y) and Rigidity modulus (μ). It is evident from Table 1 that the elastic constants are significantly less in human when compared to that of horse hair. This aspect can be attributed to molecular architecture; and assembly and thickness of fibers of the hair with respect to animal.

Table 1 - Elastic constants of Keratinized tissue - The Hair

Name of Sample	*Young's Modulus,Y ($x10^{11} dyne/cm^2$)*	*Rigidity Modulus,μ ($x10^{11} dyne/cm^2$)*	*Bulk Modulus,K ($x10^{11} dyne/cm^2$)*	*Poisson's Ratio,σ*
Horse hair	0.501	0.136	0.240	0.848
Human hair	0.129	0.058	0.056	0.112

The presence of intermediate filaments between the fibrils and also the cross linkages contributes a lot in the elastic behavior of hair. The number of filaments and cross linkages varies with the thickness of hair. Further, hair contains both organic (keratin) and inorganic (calcium phosphate) materials. The variation in the elastic parameters can also be attributed to the degree of calcium phosphate deposition.

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