CALIFORNIA STATE SCIENCE FAIR
2003 PROJECT SUMMARY

Name(s)

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Project Number

J1816

Project Title

How Do Heat and Hydration Affect the Tensile Properties of Human Hair Fibers?

Abstract

Objectives/Goals

(1) Study a full spectrum of tensile properties of keratin-based fibers (human hair), beyond simple tensile strength (e.g., generate full stress/strain curves).
(2) Explore how heat & hydration, which alter protein structure, act to affect the tensile properties of individual keratin-based fibers.
(3) Key is to successfully design and build a practical, inexpensive, and accurate mechanism that can generate full stress/strain curves for single fibers, and to make a time-effective methodology that overcomes the problem of high variability between different hairs.

Methods/Materials

An inexpensive stress/strain assessing mechanism (SSAM) was designed to precisely apply stresses to single fibers and measure resulting strains. It uses a Hookes law ideal spring & a camcorder to capture data on-the-fly for later analysis. A fiber has each end threaded in a needle, tied, and glued. Needles are clamped into the SSAM. Tensile properties of 32 normal hair fibers were studied to refine and prove the SSAM. Stress/strain curve analysis successfully gave 7 measures for each: Youngs modulus (stiffness) pre-yield, yield stress & strain, post-yield modulus, pre-breakage modulus, and breakage stress & strain.

Results

Tensile properties varied greatly between hairs, so paired internal controls were developed. A hair is divided, one half used as control for its twin, reducing variability. Heat, 95-100 °C, 2-3 hrs, was applied to one half of each of 15 hairs. Heated fibers showed less elasticity over a longer range of stresses than their unheated twins. Many yield points nearly disappeared. Hydration at 40-45 °C, 2-3 hrs, was also studied on 21 fibers. Water increased elasticity & reduced yield stress, compared to their dry twins. Finally, stretching & releasing fibers showed fibers return to their original length if strain is low, but they lose an ability to recover (even overnight) if strained past the yield point.

Conclusions/Discussion

My new SSAM & procedures worked well to make single fiber stress/strain curves, and internal controls overcame variability problems. High heat makes keratin fibers stiffer and hydration raises elasticity & eases yield. Interestingly, keratin fiber stress/strain curves seem counterintuitive: When stretched, they are first stiff, then loose, then stiff again, before breaking. A model with a spring-like structure having cross-links is proposed to account for this behavior.

Summary Statement

This is a study to find a way to do detailed studies of keratin-fiber tensile properties, and to then use that methodology to explore the effects of heat and hydration on single human hair fibers.

Help Received

Father assisted with power tools in constructing the SSAM, and with the circuit design for the motor controller.