E2 Differentiation of Human, Animal, and Synthetic Hair by ATR-FTIR Spectroscopy

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After attending this presentation, attendees will understand the current problems forensic hair analysis faces and how Attenuated Total Reflectance-Fourier Transform Infrared (ATR-FTIR) spectroscopy combined with chemometrics provides a faster, quantitative, and inexpensive method for hair identification.

This presentation will impact the forensic science community by demonstrating a method that is able to quantitatively identify a sample of hair as human with no false negative human assignments, using a non-destructive and rapid approach without the need for sample preparation or specialization.

Hair fibers are ubiquitous to every environment and are a common form of trace evidence found at crime scenes. The primary difficulty forensic examiners face after retrieving a hair sample is determining its origin: if it came from a human or an animal and, if human, what is the race, gender, and type of body hair (e.g., head, pubic, underarm, etc.). Currently, the methodology of microscopic examination of potential hair evidence is absent of statistical probability and is inherently subjective.[1] In the 2009 National Academy of Sciences Report, *Strengthening Forensic Science in the United States: A Path Forward*, it was concluded that there are no accepted statistics about the frequency with which certain hair characteristics are distributed within a population and that hair comparisons for individualization have no scientific support without nuclear DNA.[2] In early 2013, the Federal Bureau of Investigation (FBI) began a review of more than 2,000 convictions based on hair evidence.[3] Of the first 310 cases, DNA analysis revealed that 72 of the convictions were grounded on faulty hair evidence.[3] Despite its increasing popularity, the process of extracting DNA is costly, destructive, time consuming, and the majority of times is unsuccessful due to its degradation and absence from the hair.[4] A method for determining the identity of an unknown fiber quickly, with a high degree of certainty, and eliminating examiner bias would be extremely useful and cost-effective for the field of forensic science.

ATR-FTIR spectroscopy is a technique rising in popularity for analytical and biological purposes. The attributes of ATR-FTIR spectroscopy are very attractive for forensics because of its rapid and non-destructive nature, its ease-of-use, and minimal-to-no-sample preparation. An infrared spectrum displays the vibrational characteristics of a sample based on the different absorption frequencies of the individual functional groups.[5] The advantage of combining ATR-FTIR spectroscopy with chemometrics is its ability to enhance the selectivity of the instrument and create classification models.[6] With the availability of portable ATR-FTIR instruments, there is the potential for on-field analysis of the identification of a single hair fiber.

This study demonstrates the ability to discriminate natural hair from a synthetic fiber and differentiate human hair from animal hair (i.e., dog and cat hairs) using chemometric modeling of ATR-FTIR spectroscopic data.[7] Two Partial Least Squares Discriminant Analysis (PLSDA) models were constructed: one to differentiate natural hair fibers from a synthetic fiber (binary) and the second discriminating human hair from animal hair (species specific). Hair samples were collected from a synthetic wig and a diverse population of humans, dogs, and cats. Of the many variables that can influence the chemical make-up of hair (bleaching, waving, straightening, and extensive sunlight exposure), only chemically treated (i.e., dye, bleaching, etc.) hairs were excluded from this study.[8] Both models were successful in differentiating these classes; synthetic hair was completely separated from natural hair in the binary approach and all human samples were correctly predicted as human in the species-specific model. An external validation, using untrained donors, resulted in zero false positive and false negative assignments for the human class; however, one of the five external dog samples, from a breed of dog not accounted for in the training dataset, was misclassified and all spectra were incorrectly predicted as cat.

Overall, this demonstrates the significance of the model's unique ability to quantitatively identify a sample of hair as human with a high degree of confidence. Most importantly, the method can be conducted without the need of a trained expert, is non-destructive, requires no sample preparation, and results in rapid identification, making it of ample importance to the field of forensic science.

References:

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