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FTIR Spectroscopic Analysis of Keratinised Tissue – The Hair

Mohammed. Ehteshamuddin Aziz, Kaleem Ahmed Jaleeli and Adeel Ahmad
Biophysics Research Laboratory, Department of Physics, Nizam College (Autonomous),
Osmania University, Hyderabad – 500 001, India
E- mail: Kaleemjaleeli@gmail.com

Abstract: ***The paper reports the FTIR data of Human and Horse Hair. The IR spectrum reveals the constituents of Hair. The constituents are Proteins, which is mainly Keratin, present in large quantity whereas Carbonate ions and Phosphate ions are relatively in small quantity. The study suggests that IR spectroscopy can be used for identification, analysis of amino acids and various ions present in the Human and Horse Hair.***

Keywords: FTIR, Hair, Keratin, Horse and Human.

I. INTRODUCTION

Infrared spectroscopy is an essential method to get the valuable information in the study of biomaterials with respect to structure of macromolecular components and their conformations within the tissue. In most of the cases, infrared spectroscopy gives rapid qualitative and quantitative identification of organic and inorganic constituents and their combinations in mineralized biological tissues. It can also supplement other physical and chemical methods of analysis for the determinations of different components present in the biomaterials.

In some cases infrared spectroscopy is helpful for the identification of inorganic and organic constituents of biomaterials. The spectral analysis of tissues of biomaterials depends upon the material present and the analytic being sought. The keratin protein is dominated by the spectrum of the macromolecular components, which are present in the large quantity.

Mohammed Ehteshamuddin Aziz et al [i], studied the mechanical properties of human and also horse hair and found that 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.

H. Panayiotou and S. Kokot [ii]. The findings indicate that spectra from the heads of two individuals of the same gender, race, hair colour, hair length, and treatment characteristics can be discriminated.

Emilia Bramanti et al [iii] studied the hair fiber divided into three regions along its axis: bulb (inferior and central), supra-bulbar zone, and shaft. The ratios seem to offer significant, reproducible parameters in differentiating the anagen, catagen, and telogen hair phase, and in estimating the degree of hair aging.

Louisfert and Pobbequin [iv] studied a variety of natural and synthetic samples of CaCo3, both individually and in mixture by infrared spectroscopy.

Posner and Perlof [v] based on IR data suggested that the mineral portions of the bone and tooth tissues are calcium deficient hydroxyl apatite.

Posner et al [vi] carried out infrared studies on synthetic hydroxyl apatite Ca10 (PO4)6 (OH)2, containing low calcium, have shown the presence of fairly strong hydrogen bonds in proportion to the missing number of calcium ions.

Ramaswamy et al [vii] studied the mineralogical form of CaCo3 deposition in some marine molluscan shells through infrared spectroscopy. They computed the percentage composition of calcite and aragonite using the characteristic frequencies of the two polymorphs and results were correlated with the different environments of the species.

Srinivasa Rao and Srinivasa Manja [viii] studied the infrared spectrum of human bone powder and ash with a view to understand the nature of hydrogen bonding in these biological apatite. The infrared spectrum revealed bands characteristic of CO3 ion and this observation suggests that bone material consists of carbonate containing apatite.

The average hydrogen bond lengths in bone powder and bone ash are estimated to be 2.76A0 and 2.80A0 respectively.

Samata and Krampitz [ix] studied Ca++ binding polypeptides in oyster shells. They reported that the basic architecture of the amino acid sequence of all Ca++ binding polypeptides is the same.

Saarakkala et al [x] observed carbohydrate region absorbance, quantified with and without normalization with amide 1 region.

A search of literature reveals that inspite of extensive investigations on infrared spectroscopy of human and animal skin, hair, nail, bone and collagen on different aspects and their constituents such as lipids and proteins, no information is available on qualitative and quantitative identification of organic and inorganic constituents and their combinations of Hair. In view of this, in the present investigation, infrared spectroscopic study has been made on Human and Horse Hair, in order to assess its molecular composition which is distributed in the Hair.

II. MATERIALS AND METHODS

The Hair samples of the animal Horse and Human were collected and cleaned. FTIR spectra of the samples were recorded with Tensor 27 Bruker optics FTIR spectrometer and

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depicted in Figure 1 and Figure 2. The data obtained from Fourier Transform Infrared spectra is presented in Table 1.

III. RESULTS AND DISCUSSION

Figure 1 and 2 shows FTIR spectrum of Human and Horse Hair. This spectrum reveals a series of bands of different intensities. Table 1 presents the data on wave numbers and corresponding Transmittance (%) obtained from FTIR spectra along with characteristic vibrations of different functional groups.

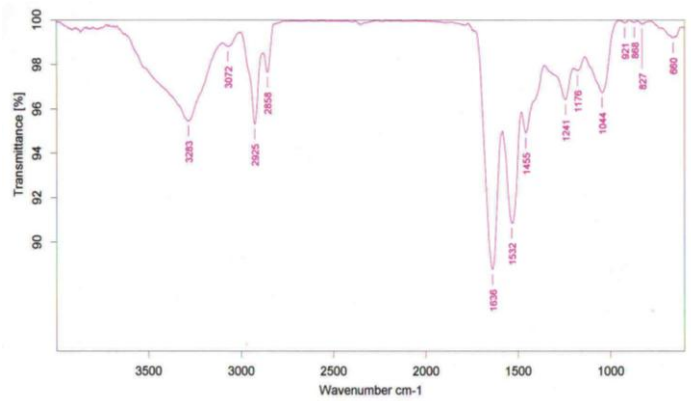

Fig. 1. FT IR spectra of Human Hair

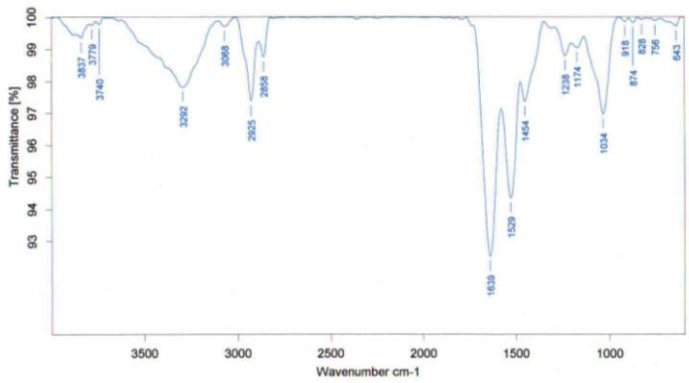

Fig. 2. FT IR spectra of Horse Hair

In order to analysis the data, The FT-IR spectrum has been divided into **five** regions.

Region I (4000 to 3200 cm^{-1}) concerned with water and carboxylic group in horse hair but the water molecules were absent in case of human hair. In this region the focus is on the revelation of the nature of hydrogen bonding and the carboxylic acids.

In Region II (3200 to 1400 cm^{-1}) the bands for functional groups are observed. The functional groups are hydrogen stretching, stretching vibrations lipid acyl group, asymmetric stretching in lipids and proteins were confirmed and the β pleated structures conformation has been obtained.

Region III (1400 – 900 cm^{-1}) has significant importance in the context of biological minerals and their combinations. The spectra of hair indicates the presence of glucose, deformation of carbohydrates and the characteristics of phosphate ion, carbon ion and also of some functional groups concerned with protein – the Keratin.

Region IV (900 – 800 cm^{-1}) gives the SO bond esters as well as deformation and out of plane bending vibrations of NO_2^-, NO_3^- and carbonate ions which can be used to get the unsaturation of Hair.

Region V (800 – 600 cm^{-1}) related to cis – double bond (=CH), N-H wagging, CO_2 absorption and SO_4^{2-} ions and NH_2.

The IR bands at wave number 3068 cm^{-1} is related to Amide B in Horse hair but not in Human hair (Table 1). The dominating bands at 1639 cm^{-1} in Horse hair and 1636 cm^{-1} in Human hair (Figure 1 and 2) provides the β pleated structural conformations of proteins from Amide I components. The wave number 1532 cm^{-1} and 1529 cm^{-1} has been observed in Human and Horse hair respectively, which may be originated due to peak region of proteins. These are related to the stretching vibrations of C=C bonds and N-H bonds respectively. A band around 1241 cm^{-1} in Human Hair is due to the C-N stretch with N-H bending vibrations and Amide III band components of protein whereas in Horse Hair the band around 1238 cm^{-1} is for phosphodiesters. The bands at 1176 cm^{-1}, 1174 cm^{-1}, 1044 cm^{-1}, 1034 cm^{-1}, 921 cm^{-1} and 918 cm^{-1} for both species are related to stretching vibrations of C-O, C-OH and C-C ring vibrations in carbohydrates. These bands are believed to be more specific to glucose. The bands at 1238 cm^{-1} for Horse Hair and 1241 cm^{-1} for Human Hair are originated from P-O anti symmetric stretch and from P = O asymmetric stretch and are related to calcium phosphate ions.

IV. CONCLUSION

The study shows that the constituents of Human and Horse Hair are mainly Keratin which is in maximum quantity and glucose (relatively in small quantity). Carbonate ions and Phosphate ions are also present but in a very small quantity.

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Table 1 – FT IR data on Human and Horse Hair

Wave number (Cm^{-1})	Transmittance %		Characteristics vibrations of functional groups
	Human	Horse	
3837 3774 3740		0.9936 0.9977 0.9979	H_2O (atmospheric absorption)
3292 3283	 0.9545	0.9782	O-H carboxylic acids and derivatives, alcohols and phenols
3072	0.9881		C-H, CH_2, C=C alkenes
3068		0.9972	Amide B, NH stretching
2925	0.9532	0.9739	C-H symmetric stretching of CH_2
2858	0.9765	0.9876	C-H symmetric stretching of CH_2 in fatty acids, symmetric stretching vibrations of lipid acyl CH_2 groups
1639 1636	 0.8880	0.9253	H-OH bending mode of water, NO_2 bond in nitro compounds, Amide I band components β region pleated structures confirmation of proteins, C=C, C=N, ($\upsilon_{C=C}$), NH_3 in υ_{as} and υ_s
1532 1529	0.9086	 0.9437	Amide II peak region – protein NH, (C-N), NO_2 bond in nitro compounds, carboxylic acids and derivatives
1455 1454	0.9492	 0.9737	CH_2, CH_3 asymmetric bending modes of lipids, proteins
1241	0.9643		Amide III band components of proteins (C-N), C-N stretching vibrations from amines from free amino acids.
1238		0.9881	P=O asymmetric stretching of PO_2^-, phosphodiesters.
1176 1174	0.9773	 0.9906	C-O, C-C, C-N, stretching C-O-H, C-O-C deformation of carbohydrates, DNA signals or maker bands
1044	0.9674		Carbohydrate bonds, suggests the C=O absorption of glycol protein
1034		0.9698	C-O amide-I band, C-N, C-C, glucose
921 918	0.9988	 0.9987	C-O, C-C, C-N, stretching C-O-H, C-O-C deformation of carbohydrates, C-H and $=CH_2$
874 868 828 827	 0.9990 0.9982	0.9984 0.9993	S-OR esters, out of plane bending, NO_2^-, NO_3^-, CO_3^{-2}
756		0.9989	Cis-R, CH=CHR
660	0.9925		NH_2 and N-H wagging, O-H bending In-plane, CO_2 (atmospheric absorption),
643		0.9978	C-H deformation, SO_4^{2-}, C-S in $\upsilon_{(C-S)}$