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Determination of Human Hair Components by Spectrophotometric Methods for the Diagnosis of Thyroid Diseases

***Fatima H. Salih*[1], *Shaimaa S. Mahdi*[1], *Alaa H. Ali*[2]**

[1] Department of physics, College of Science for Women, Baghdad University, Baghdad, Iraq.
[2]Ministry of Science and Technology, Baghdad, Iraq.
*Correspond author.

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Abstract

Human hair is a vital tissue, rich in minerals and vitamins that have an effective role in the production of enzymes, hormones and other substances necessary for normal growth, it is considered an indicator of any defect in the performance of body functions at all stages of life, so the use of hair in the diagnosis of diseases is a challenge in the clinical laboratory, as it will be easy to frequently monitor diseases, and it will have an impact on medical research and treatment. For instance, hypothyroidism occurs when the thyroid gland does not secrete enough thyroid hormone into the blood. If neglected, it may lead to health problems including high cholesterol and cardiac issues. In this research, physical techniques were employed to detect hypothyroidism using a single human hair, as the optimal use of science gives an opportunity to consider hair as a tool in diagnosing diseases. Among these modern physical techniques, FTIR and Raman spectral techniques were adapted. The FTIR technique enables the identification of the compounds as well as the difference between people with healthy function and those who have hypothyroidism. Additionally, this approach demonstrated that those with hypothyroidism had high levels of harmful cholesterol. This was proven using the Raman spectral technique, which gave similar and complementary results obtained by the FTIR technique.

Keywords: FTIR Spectroscopy, Hypothyroid, Human hair, lipids, Raman Spectroscopy.

Introduction

Hypothyroidism is one of the most prevalent functional complications of thyroid diseases[1-3]. The bloodstream's level of thyroid hormone is insufficient, which causes the body's metabolism to stop functioning. According to the fact that people with hypothyroidism frequently have higher levels of protein, glucose, and low-density lipoprotein cholesterol (LDL). Due to the elevated levels of LDL cholesterol. Additionally, hypothyroidism can also lead to weight gain, fatigue, and depression, further contributing to the risk of heart disease. Diagnosing diseases using human hair is more challenging in the clinical laboratory than in blood. Hair could be removed effortlessly without causing the patient any pain. In comparison to blood, element concentrations, particularly trace elements, are typically 10 to 50 times greater in hair[4,5]. These larger concentrations allow for the measurement of more components in hair than in blood. More than 32% of hair's weight is made up of water, while pigments, lipids and proteins make up about 65% of its weight[6]. Chemically, keratin, a protein that makes up around

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80% of human hair, has a considerable quantity of sulfur from the amino acid cysteine, which is capable of being deoxidized in the disulfide binding form[6]. The main Elements in Hair are Zinc (Zn), Calcium (Ca), Copper (Cu), Selenium (Se), Magnesium (Mg), Chromium (Cr), Manganese (Mn), Cadmium (Cd), Mercury (Hg), Sodium (Na), Potassium (K), Iron (Fe), Nickel (Ni), Aluminum (Al), Silver (Ag), Sulphur(S), Phosphorus(P), Cobalt (Co), Arsenic (As), Lithium (Li), and Iodine (I). In addition to the cysteine, which is so stable that human hair is occasionally discovered undamaged even years after death. Which enables physicians to check for illnesses. Therefore, hair diagnostics have the potential to revolutionize medical research.

Recently, the improved scientific application has made it possible to use hair as a diagnostic tool for diseases efficiently and rapidly. When it is possible to use contemporary physical techniques in the field of medicine, The first technique is Fourier transform infrared (FTIR). Several studies have investigated the potential of FTIR analysis of hair samples for diagnosing and screening thyroid disorders. Thyroid hormones control numerous metabolic processes in the human body, and changes in thyroid hormone levels can affect the chemical composition of hair[7]. Researchers have hypothesized that the changes in molecules like proteins and lipids in the hair of patients with thyroid disorders could generate distinctive infrared absorption spectra that FTIR spectroscopy could detect.

analyzed hair samples from 30 female patients with clinically diagnosed thyroid disorders and 30 age-matched healthy female controls using FTIR spectroscopy. The researchers found significant differences in the FTIR spectra between the hair samples of patients and controls, indicating differences in their chemical composition. The researchers analyzed certain peaks in the FTIR spectra corresponding to specific molecular bonds, including tyrosine, cysteine and lipids. They found lower levels of tyrosine and cysteine in the hair samples of patients compared to controls, suggesting lower levels of these amino acids in patients with thyroid disorders. The second technique is Raman Spectroscopy, which has been investigated as a potential technique for analyzing hair samples to diagnose and screen for thyroid disorders. Abnormal thyroid hormone levels in patients can lead to changes in the proteins, lipids and other molecules present in hair. Researchers have hypothesized that these chemical changes could generate distinct Raman scattering spectra that could differentiate patients from healthy individuals[8,9].

Another study analyzed hair samples from 50 patients with hyperthyroidism, 50 patients with hypothyroidism and 50 healthy controls using Raman spectroscopy. The researchers detected clear differences in the Raman spectra of hair samples between all patient groups and controls[10]. They reported that Raman spectra could accurately classify patients with thyroid disorders from healthy controls with 92% sensitivity and 90% specificity. The researchers suggested that Raman spectroscopy of hair samples has potential for thyroid screening and monitoring[11].

Patients with hypothyroidism require routine check-ups and they need to have their thyroid function monitored constantly. Therefore, this study aims to develop new techniques based on physical methods that enable physicians to monitor diseases frequently and easily while also having an impact on medical research and therapy. Using the molecular spectroscopy techniques FTIR and Raman spectroscopy, the bio-molecular changes in the hair could be precisely examined. These techniques have the potential to provide valuable insights into the progression of hypothyroidism and aid in the early detection of any abnormalities. Additionally, studying bio-molecular changes in hair could offer a non-invasive and cost-effective approach for monitoring thyroid function in patients, improving their overall quality of life.

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Materials and Methods

In this examination, the technical aspect will be discussed using modern spectral analysis methods, where the research was carried out for people with hypothyroidism diseases in addition to the control. The laboratory blood test was required to ensure that they have only a hypothyroidism problem, which means that the thyroid hormone is below the normal range. Hair samples were obtained from women with hypothyroidism between the ages of (40, 50) years, and the control (30 years old) that does not suffer from hypothyroidism. All examined samples of the Hair have been extracted from the hair roots. The Hair samples were cut into very small pieces the lengths of which ranged between (0.5-1) mm, then mixed with potassium bromide (KBr), which consists of Potassium Salt and Bromide. The produced mixture was ground by an Iron mortar until it became more like a powder, and then it was placed inside a press so that it became a transparent disc with a thickness of 2 mm.

Results and discussion

FT-IR Spectroscopic Technique

FTIR spectroscopy is one type of molecular spectroscopy that is used to examine the bio-molecular changes in the hair with details. This technique allows the detection of the biochemical composition of a biological sample and its relation to the different macromolecules. For instance, nucleic acids, carbohydrates, lipids, and proteins allow the identification of functional groups, molecular conformations, types of bonds and interactions between the different molecules. Therefore, this technique could be used to study the components of more complex biological samples, such as cells, tissues and body fluids[12,13]. Every chemical or biochemical sample has its own IR spectrum, which is reflected in the presence of a unique IR fingerprint assigned to each examination. Any changes in biomolecules caused by pathological conditions lead to changes in the fingerprint, enabling distinguishing between healthy and diseased cells.

In contrast to histopathologic methods, infrared FTIR spectroscopy is a rapid, inexpensive, metabolic method that requires only a small amount of sample. This method distinguishes samples with distinct metabolic profiles and provides information on the biochemical composition of the samples.

FTIR is the most widely used technique for infrared spectroscopy. A sample is subjected to IR radiation during infrared spectroscopy. The sample takes in some of the infrared radiation and sends some through it. A molecular fingerprint of the sample is created by the resulting spectrum, which depicts the molecular absorption and transmission[14]. The infrared spectrum of two distinct molecular structures is unique, just like a fingerprint. In our Research, the samples were measured using the FTIR spectrometer from Perkin Elmer model (Spectra Two) with a spectrum range of 4000 - 400 cm^{-1} and a resolution of 1 cm^{-1}. Table 1 represents the selected samples with the percentage of thyroid hormone in the blood. Table 2. Gives specific information about the samples incorporated in this research.

Table 1. It represents the selected samples with the percentage of thyroid hormone in the blood.

The samples	The age	Thyroid blood tests results (T.S.H)	Normal Range
Sample 1 (control)	30	1.517	0.38-4.31
Sample 2 (Hypothyroidism)	40	5.32	0.4-4.0
Sample 3 (Hypothyroidism)	50	14.120	0.38-4.31

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Table 2. FTIR measurements show the band assignments of sample 1 (Control) single hair fiber.

S. No	Wavenumber (cm^{-1})	Vibrational Band Assignments
1	3934.58	Stretching O-H symmetric (Water)
2	3402.55	N-H proline (group of creatine)
3	2924.33	C-H stretching bonds in malignant and normal tissues CH_2 of lipids (fat)
4	2856.67	CH_2 of lipids (fat)
5	2362.32	N-H component / Proline.
6	2338.95	N-H component (Amino _ related component).
7	2116.00	C≡C terminal alkyne (monosubstituted)
8	1653.89	C=O, C=N, N-H of adenine, thymine, guanine, cytosine unordered random coils and turns of (amide I).
9	1540.08	Stretching C=N, C=C guanine (protein).
10	1457.19	C-O-H stretching (protein and collagen).
11	1233.66	Stretching (Po_2) asymmetric overlapping of the protein (amid III) and the nucleic acid phosphate vibration, relatively specific for collagen.
12	1085.73	Si-O-Si stretching (organic silicone).
13	671.12	C-H lipids and protein groups (LDL)
14	472.01	S-S stretching (systine) group of creatine.

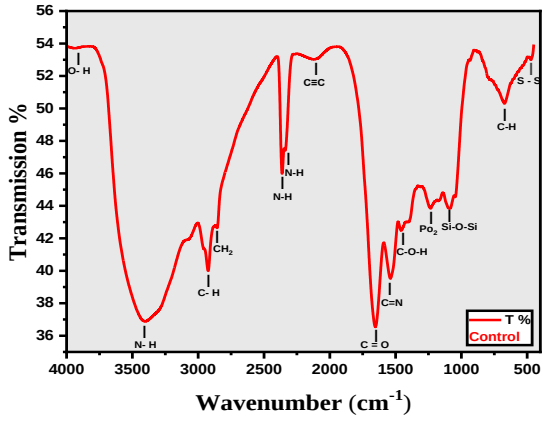

Figure 1. FTIR spectra of Control hair fiber of sample 1.

Table 3. FTIR measurements shows the band assignments of a sample 2 single hair fiber.

S. No	Wavenumber (cm^{-1})	Vibrational Band Assignments
1	3941.46	Stretching O-H symmetric (Water)
2	3413.77	O-H ammonium for hydroxyl compound.
3	2957.91	CH_3 of lipids (fat)
4	2925.03	CH_2 of lipids (fat)
5	2854.56	CH_2 of lipids (fat)
6	2362.97	N-H component (proline)
7	2343.46	N-H component (Amino – Related Component)
8	2080.21	C-H both of lipids and protein group (LDL).
9	1651.93	C=O, C=N, N-H of adenine, thymine, guanine, cytosine.
10	1538.72	Stretching C=N, C=C guanine (protein).
11	1455.79	C-O-H stretching (protein and collagen).
12	1385.83	CH_3 methyl (nitrate ion)
13	1317.71	O-H bending (water)
14	1232.04	Stretching (Po_2) asymmetric overlapping of the protein.
15	1168.41	C-N stretch (secondary Amino).
16	1090.30	Si-O-Si stretching (organic silicone).
17	1045.57	C-O-O-C stretching (carbohydrates).
18	846.17	C-H lipids and protein groups (LDL).
19	779.99	C-H lipids and protein groups (LDL).
20	668.24	C-H lipids and protein groups (LDL).
21	618.37	C-H lipids and protein groups (LDL).
22	474.61	S-S stretching (systine) group of creatine.
23	467.36	S-S stretching (systine) group of creatine.

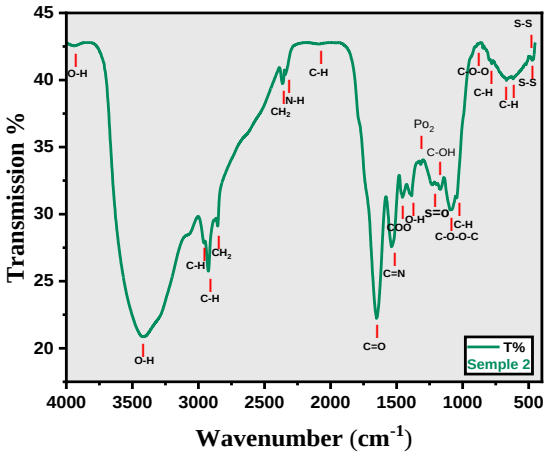

Figure 2. FTIR spectra of Hypothyroidism hair fiber of sample 2.

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Table 4. FTIR measurements shows the band assignments of a sample 3 single hair fiber.

S. No	Wavenumber (cm^{-1})	Vibrational Band Assignments
1	3943.28	Stretching O-H symmetric (Water)
2	3402.43	N-H proline (group of creatine)
3	2958.31	CH_3 stretching of lipids (fat)
4	2924.93	CH_2 of lipids (fat)
5	2874.85	CH_2 stretching mode of the methylene chains membrane lipids (fat)
6	2854.21	CH_2 of lipids (fat)
7	2364.66	N-H component (proline)
8	2099.15	C-H both of lipids and protein group (LDL).
9	1654.30	C=O, C=N, N-H of adenine, thymine, guanine, cytosine.
10	1540.63	Stretching C=N, C=C guanine (protein).
11	1454.84	C-O-H stretching (protein and collagen).
12	1400.74	Symmetric stretching vibration of (COO) group of fatty acids and amino acids.
13	1315.73	O-H bending (water)
14	1236.37	Stretching (Po_2) asymmetric overlapping of the protein.
15	1199.84	S=O stretching of (Taurine).
16	1166.49	C-O of protein and carbohydrates.
17	1079.16	C=O stretching vibration of the amide.
18	1045.51	C-O-O-C stretching (carbohydrates).
19	900.48	C-H lipids and protein groups (LDL).
20	875.72	Peroxide C-O-O stretching group of fatty acids and amino acids.
21	846.29	C-H lipids and protein groups (LDL)
22	778.77	C-H lipids and protein groups (LDL)
23	668.54	C-H lipids and protein groups (LDL)
24	618.01	C-H lipids and protein groups (LDL).
25	474.15	S-S stretching (systine) group of creatine.
26	467.15	S-S stretching (systine) group of creatine.

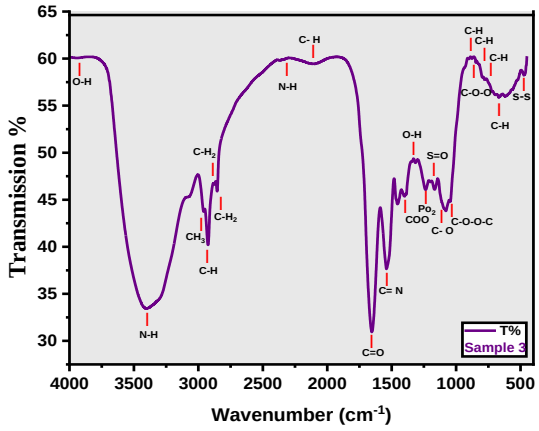

Figure 3. FTIR spectra of Hypothyroidism hair fiber of sample 3

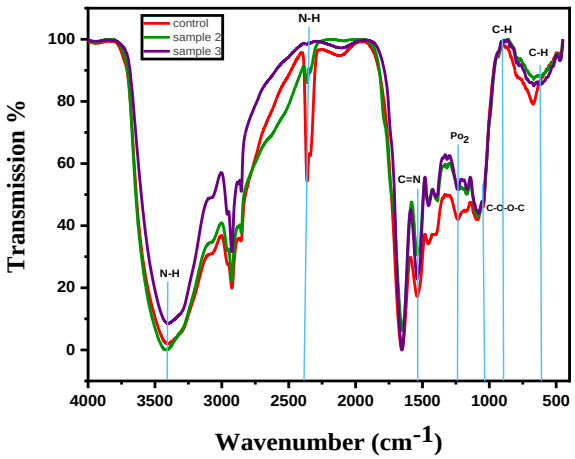

Figure 4. Normalized spectra of FTIR measurements.

In general, hair consists of α-keratin, proteins, lipids, carbohydrates, and water. It was found that people who suffer from hypothyroidism often have high levels of bad cholesterol (LDL)[15] as well as, a decrease in creatine and collagen. This is what was found practically in our research, as shown in the tables 2,3,4 for the three samples, which proved an increase in the number of recurrences of the associations of low-density lipoprotein (LDL), the bad cholesterol for the hypothyroid cases, where it was double that of the control, according to the percentage of the disease shown in the table1. Figs. 1,2,3 show the FTIR spectra of the chosen samples in this work. The peak analyses and interpretation are clearly listed in Tables 2, 3, 4. Fig. 4 shows the normalized spectra of FTIR, it is noticeable that the C-H bond appeared clearly at the wavenumber of 618 cm^{-1} for both samples 2,3. This bond is represented

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by the lipids group (LDL), while the peak of this bond is much lower for the control. This is also true for the C-H bond at 900cm^{-1}, which represents the presence of the lipid group of (LDL). Additionally, the peak of the control located at 3402cm^{-1} is attributed to the creatine (N-H bond) which was much higher compared to the two hypothyroid cases. The highest permeability obtained is at 2362 cm^{-1} with the N-H bond, which represents the amino group of creatine, showing a large difference due to the increase in the amount of creatine for the control and its significant decrease in the samples with hypothyroidism. Which means that creatine is influenced by thyroid diseases. On the other hand, the percentage of proteins shown at the peak of 1236 cm^{-1} represented by Po_2 in the control spectrum was higher than in both samples 2,3 respectively. One of the most important proteins needed to build hair is collagen, which is located in Fig. 4 at 1540cm^{-1} by the C=N bond. This peak appears clearly high in the control when compared to the hypothyroid samples. the C-O-O-C bond appears at 1045cm^{-1} due to higher carbohydrates in control versus hypothyroid samples.

Raman spectroscopic technique

The principle in Raman spectroscopy is based on the phenomenon of Raman scattering. In order to be able to study molecules in Raman spectroscopy, the polarizability of these molecules must be changed by stimulating the molecule to rotate or vibrate. In Raman spectroscopy, the material to be studied is exposed to radiation from monochromatic light, often using a laser. The frequency spectrum of a material contains, the frequency of the light at which it was irradiated (Raleigh scattering). In addition to the frequencies resulting from the internal energy of the material, which are characteristic of each material according to its composition. This internal energy is the result of physical processes within the particles of matter such as rotation, oscillation, quantum vibrations, and others. The lines seen in Raman spectroscopy are known as Stokes lines[16-18].

The interaction between matter and light results in a transfer of energy from light to matter, which is known as the Stokes shift of the spectrum, and a transfer of energy from matter to light, which is known as the anti-Stokes shift. Since the wavelength of light relates to its energy, the transmission of energy causes a change in the wavelength of the light emitted by the material compared to the incoming light, which is known as the Raman shift[19-21].

532 Preconfigured Raman Spectrometer was used to analyze the samples. The operating mode is CW with a power output of > 1.5,10,20,200 (mw) and spectral line width of < 0.00001 (nm). Figs., 6, 7, 8 show the Raman spectroscopic spectra of the tested samples in this work.

Table5. Raman measurements show the band assignments of a sample 1 (Control) single hair fiber.

S. No	Wavenumber (cm^{-1})	Vibrational Band Assignments
1	3932.998	Stretching O-H symmetric (Water)
2	3402.107	N-H proline (group of creatine)
3	2925.335	CH_2 of lipids (fat)
4	2855.752	CH_2 of lipids (fat)
5	2363.518	N-H component / Proline.
6	2337.747	N-H component (Amino _ related component).
7	2116.112	C≡C terminal alkyne (monosubstituted)
8	1654.804	C=O, C=N, N-H of adenine, thymine, guanine, cytosine.
9	1541.409	Stretching C=N, C=C guanine (protein).
10	1456.364	C-O-H stretching (protein and collagen).
11	1232.152	Stretching (Po2) asymmetric overlapping of the protein.
12	1085.255	Si-O-Si stretching (organic silicone).
13	670.335	C-H lipids and protein groups (LDL)
14	471.895	S-S stretching (systine) group of creatine.

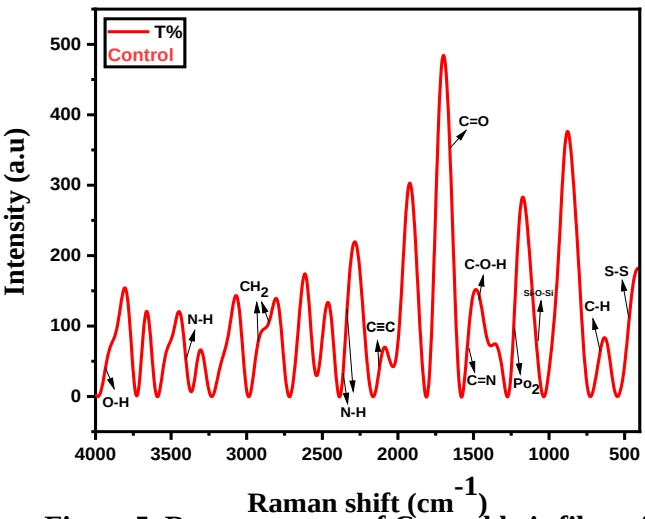

Figure 5. Raman spectra of Control hair fiber of sample 1.

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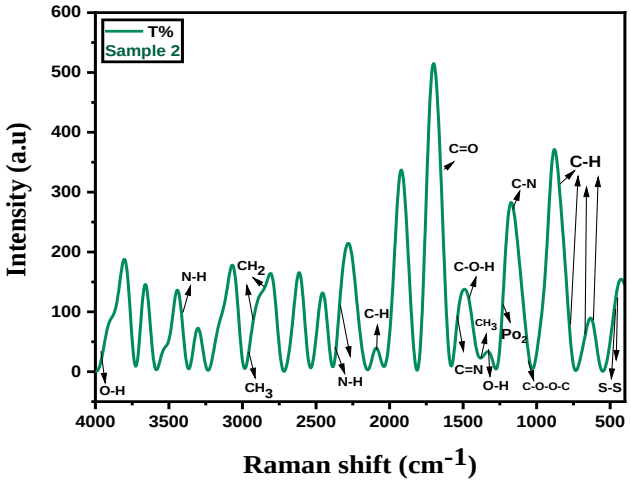

Figure 6. Raman spectra of Hypothyroidism hair fiber of sample 2.

Table 6. Raman measurements shows the band assignments of a sample 2 single hair fiber.

S. No	Wavenumber (cm^{-1})	Vibrational Band Assignments
1	3940.729	Stretching O-H symmetric (Water)
2	3412.415	N-H ammonium for hydroxyl compound.
3	2958.838	CH_3 of lipids (fat)
4	2925.335	CH_2 of lipids (fat)
5	2853.175	CH_2 of lipids (fat)
6	2363.518	N-H component (proline)
7	2340.324	N-H component (Amino – Related Component)
8	2080.032	C-H both of lipids and protein group (LDL).
9	1652.227	C=O, C=N, N-H of adenine, thymine, guanine, cytosine.
10	1538.832	Stretching C=N, C=C guanine (protein).
11	1456.364	C-O-H stretching (protein and collagen).
12	1386.781	CH_3 methyl (nitrate ion)
13	1317.198	O-H bending (water)
14	1232.152	Stretching (Po_2) asymmetric overlapping of the protein.
15	1167.724	C-N stretch (secondary Amino).
16	1090.409	Si-O-Si stretching (organic silicone).
17	1046.598	C-O-O-C stretching (carbohydrates).
18	845.581	C-H lipids and protein groups (LDL).
19	778.575	C-H lipids and protein groups (LDL).
20	667.758	C-H lipids and protein groups (LDL).
21	618.792	C-H lipids and protein groups (LDL).
22	474.472	S-S stretching (systine) group of creatine.
23	466.741	S-S stretching (systine) group of creatine.

Table 7. Raman measurements shows the band assignments of a sample 3 single hair fiber.

S. No	Wavenumber (cm^{-1})	Vibrational Band Assignments
1	3943.307	Stretching O-H symmetric (Water)
2	3402.107	N-H proline (group of creatine)
3	2958.838	CH_3 stretching of lipids (fat)
4	2925.335	CH_2 of lipids (fat)
5	2873.792	CH_2 stretching mode of the methylene chains membrane lipids (fat)
6	2855.752	CH_2 of lipids (fat)
7	2363.518	N-H component (proline)
8	2098.072	C-H both of lipids and protein group (LDL).
9	1654.804	C=O, C=N, N-H of adenine, thymine, guanine, cytosine.
10	1541.409	Stretching C=N, C=C guanine (protein).
11	1453.787	C-O-H stretching (protein and collagen).
12	1402.244	Symmetric stretching vibration of (COO) group of fatty acids and amino acids.
13	1314.621	O-H bending (water)
14	1237.307	Stretching (Po_2) asymmetric overlapping of the protein.
15	1199.649	S=O stretching of (Taurine).
16	1167.724	C-O of protein and carbohydrates.
17	1077.524	C=O stretching vibration of the amide.
18	1044.021	C-O-O-C stretching (carbohydrates).
19	902.278	C-H lipids and protein groups (LDL).
20	876.507	Peroxide C-O-O stretching group of fatty acids and amino acids.
21	845.581	C-H lipids and protein groups (LDL)
22	778.575	C-H lipids and protein groups (LDL)
23	667.758	C-H lipids and protein groups (LDL)
24	618.792	C-H lipids and protein groups (LDL).
25	474.472	S-S stretching (systine) group of creatine.
26	466.741	S-S stretching (systine) group of creatine.

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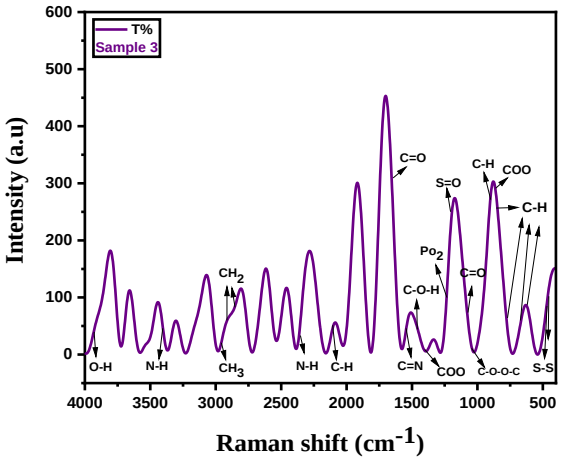

Figure 7. Raman spectra of Hypothyroidism hair fiber of sample 3.

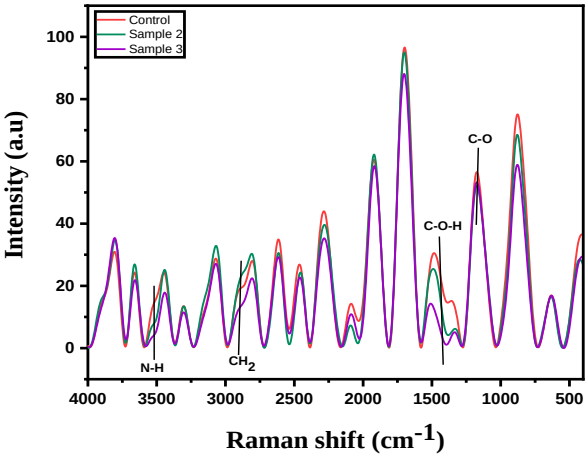

Figure 8. Normalized spectra of Raman measurements.

Raman spectral technique has been shown accurate information about the molecular structure of the hair material used in this research. The obtained results of Raman spectroscopy agree well with the illustrated results by FTIR spectral technique as shown in Tables 5,6,7. Fig. 8 presents the Normalized spectra obtained from Raman experiments. The observed bonds provide evidence to our demonstrated results that the increased LDL cholesterol and reduced thyroid activity are related. Furthermore, the low level of proteins that are found in healthy hair the difference was clear at the N-H bond at 3510 cm^{-1}, which represents an increase in the proline group of creatine in the control case and its decrease in cases with hypothyroidism. This was proven at 1453 cm^{-1} with a C-O-H bond, which shows an increase in the proportion of protein in the healthy sample and a decrease in the infected sample. In addition, the percentage of collagen and carbohydrates were much lower in the patients than in the control. This was represented by the C-O bond of 1172 cm^{-1}. At peak of 2873 cm^{-1}, which represents the CH_2 bond of lipids stretching, the patients show high intensity than the control.

Conclusion

In this research, the main components of human hair by using FTIR and Raman spectral techniques were identified and demonstrated. In the medical field, this is being effort used as a technique of diagnosis between healthy people and those with hypothyroidism. The results indicate that the two methods can be interpreted as having contributed to the patients' increased LDL cholesterol and decreased levels of the major hair-supporting proteins, creatine, and collagen.

These methods are characterized accurately to enable physicians to periodically examine the patient by using a single hair instead of the common method of drawing blood and analyzing it. Table.8 represents a comparison between the traditional method of analysis and the method used in this research.

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Table 8. Comparison between blood tests and modern physical methods

Efficiency comparison	Blood Test	FTIR and Raman techniques
1/Time	It takes a longer time to get the result. It depends on the mechanism of drawing blood and separating it to extract the serum, prepare it, and insert it into the device until the result appears.	A shorter time, as a single hair is inserted into the device and the result appears immediately after the inclusion of the database of hair minerals that are affected by hypothyroidism.
2/Cost	A higher cost due to the need for materials that are used only once.	Less cost, because the device is self-usable without additions.
3/Accuracy	Less accuracy, as it sometimes needs to be re-examined more than once, and it may be affected by the substance (liquid Detection buffer added, according to the manufacturer or the Expire.	Higher accuracy because the process depends on the main vital elements in human hair.

Author's Declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for re-publication, which is attached to the manuscript.
- No animal studies are present in the manuscript.
- Authors sign on ethical consideration's approval.
- Ethical Clearance: The project was approved by the local ethical committee at University of Baghdad.

Authors Contributions

Study conception and design: A. H. A.; data collection: F. H. S.; analysis and interpretation of results: Fatima H. Salih, Shaimaa S. Mahdi; draft manuscript preparation: F.H. S., Sh. S. M. All authors reviewed the results and approved. the final version of the manuscript.

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تحديد مكونات شعر الانسان بالطرق الطيفية لتشخيص أمراض الغدة الدرقية

فاطمة هادي صالح [1] ، شيماء صالح مهدي [1]، علاء حسين علي[2]

[1]قسم الفيزياء، كلية العلوم للبنات، جامعة بغداد، بغداد، العراق
[2]وزارة العلوم والتكنولوجيا، بغداد، العراق

الخلاصة

يعد شعر الانسان نسيج حيوي غني بالمعادن والفيتامينات التي لها دور فعال في انتاج الانزيمات والهرمونات والمواد الاخرى اللازمة للنمو الطبيعي حيث تعتبر كمؤشر لأي خلل في اداء وظائف الجسم في جميع المراحل العمرية، لذلك يعد استخدام الشعر في تشخيص الامراض تحدياً في المختبر السريري حيث سيمكن الأطباء من مراقبة الأمراض بشكل سهل ومتكرر وسيكون لها تأثير على البحث الطبي والعلاج .يحدث مرض قصور الغدة الدرقية عندما لا تفرز الغدة الدرقية ما يكفي من هرمون الغدة الدرقي في مجرى الدم وقد يؤدي عدم علاجه الى مشكلات صحية مثل ارتفاع مستوى الكوليسترول ومشكلات القلب .في هذا البحث تم توظيف تقنيات فيزيائية للكشف عن مرض قصور الغدة الدرقية باستخدام شعر الانسان حيث ان الاستخدام الامثل للعلم يعطي فرصة لاعتبار الشعر اداة في تشخيص الامراض، من ضمن هذه التقنيات الفيزيائية الحديثة تم استخدام تقنية FTIR وتقنية رامان الطيفية .حيث اعطت تقنية FTIR نتائج بينت الفرق بين مكونات الشعر في العينة السليمة والعينة المصابة بمرض قصور الغدة الدرقية .اوضحت ايضا ارتفاع نسبة الكوليسترول الضار في جسم الانسان المصاب .هذا ما اثبتته تقنية رامان الطيفية حيث اعطت نتائج مشابهة ومكملة لما أعطته تقنية FTIR.

الكلمات المفتاحية :مطيافية الاشعة تحت الحمراءFTIR، قصور الغدة الدرقية، شعر بشري، الدهون، مطيافية رامان.