Imam Mohammad Ibn Saud Islamic University

College of Science

Department of Chemistry

Study of the spectral properties of raw Hibiscus and Turmeric pigments

A graduation research project

Submitted to the Department of Chemistry in partial fulfillment of the requirements for the completion of the degree of Bachelor of Science in Chemistry

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Thank you to all the faculty and staff who have guided and inspired me throughout my studies. Your dedication and support have made a significant impact on my academic journey.

The main objective

Investigation of the spectral profile of crude pigments extracts from turmeric and hibiscus

The specific objective

1. Extracts the crude pigments from turmeric and hibiscus
2. Analyze the U.V spectral of crude pigments extracts from turmeric and hibiscus
3. Analyze the FTIR spectral of crude pigments extracts from turmeric and hibiscus
4. Analyze the HPLC spectral of crude pigments extracts from and hibiscus

ملخص البحث

تتناول هذه الدراسة المظهر الطيفي لمستخلصات الصبغة الخام من الكركم (Curcuma longa) والكركديه (Hibiscus sabdariffa)، مع التركيز على تركيبها الكيميائي وخصائصها. الهدف الرئيسي هو استخراج هذه الأصباغ وتحليلها باستخدام التحليل الطيفي للأشعة فوق البنفسجية والمرئية، والتحليل الطيفي لتحويل فورييه للأشعة تحت الحمراء(FTIR) ، والتحليل اللوني السائل عالي الأداء(HPLC) . لقد كشف التحليل الطيفي للأشعة فوق البنفسجية والمرئية عن قمم امتصاص مميزة، حيث يظهر الكركم قمة واضحة وجلية عند 310 نانومتر، مما يشير إلى وجود الكركمين، بينما يظهر الكركديه قممًا حوالي 315 و 524 نانومتر، وهي سمة من سمات الأنثوسيانين. تم العثور على طاقة فجوة النطاق المحسوبة للكركم بحوالي 4 فولت، في حين أظهر الكركديه فجوة نطاق تبلغ حوالي 3.94 و 2.37 فولت. تشير هذه القيم إلى تطبيقات محتملة في الأجهزة الضوئية والملونات الطبيعية. كشف التحليل الطيفي HPLC و FTIR وجود الكركمين في الكركم والأنثوسيانين في الكركديه. تعزز النتائج فهمنا للخصائص الطيفية لهذه الملونات الطبيعية، مما يدل على تطبيقاتها المحتملة في الأغذية والمنسوجات ومستحضرات التجميل كبدائل صديقة للبيئة للأصباغ الاصطناعية. يؤكد هذا البحث على أهمية تسخير أصباغ النباتات الطبيعية لممارسات الصناعة المستدامة.

Abstract

This study examines the spectral profile of crude pigment extracts from turmeric (Curcuma longa) and hibiscus (Hibiscus sabdariffa), focusing on their chemical composition and properties. The main objective is to extract these pigments and analyze them using UV-Vis spectroscopy, Fourier Transform Infrared (FTIR) spectroscopy, and High-Performance Liquid Chromatography (HPLC). UV-Vis spectroscopy reveals distinct absorption peaks, with turmeric displaying a prominent peak at 310 nm, indicating the presence of curcumin, while hibiscus exhibits peaks around 315 and 524 nm, characteristic of anthocyanins. The calculated band gap energy for turmeric was found to be approximately 4 eV, while hibiscus exhibited a band gap of around 3.94 and 2.37 eV. These values suggest potential applications in photonic devices and natural colorants. HPLC and FTIR analyses confirmed the presence of curcumin in turmeric and anthocyanins in hibiscus. The results enhance our understanding of the spectral properties of these natural colorants, demonstrating their potential applications in food, textiles, and cosmetics as environmentally friendly alternatives to synthetic dyes. This research underscores the importance of harnessing natural plant dyes for sustainable industrial practices.

CHAPTER ONE

GENERAL INTRODUCTION

1.Natural plant pigments

Pigments are natural substances in plants that account for their vivid hues. These pigments play crucial roles, including photosynthesis, pollination, and defense against environmental stress. Diverse pigments are located in many plant sections, such as leaves, flowers, fruits, seeds, and roots. Natural plant pigments have been utilized for ages to provide vivid colors to textiles, food, cosmetics, and artworks. These colors are derived from many plant components, such as leaves, flowers, roots, stems, bark, and seeds, rendering them a sustainable substitute for synthetic pigments. Historically, natural pigments constituted a vital aspect of cultural heritage, with civilizations like the Egyptians, Indians, and Chinese employing plant-derived colorants for textiles, rituals, and artistic expression. Currently, with the increasing environmental concerns, the utilization of eco-friendly, non-toxic, and biodegradable pigments has garnered fresh attention across multiple industries. The natural provenance and chemical variety of these pigments render them a superior option to manufactured colorants, frequently linked to environmental contamination and health hazards **[1].**

2.Types and sources of natural plant pigments

The primary types of plant pigments include chlorophylls, carotenoids, anthocyanins, flavonoids, betalains, and tannins.

2.1Chlorophylls (Green Pigments)

Chlorophyll is the most abundant pigment in plants and is responsible for their green color. It plays a critical role in photosynthesis by absorbing light energy and converting it into chemical energy. There are two main types: Chlorophyll-a: Found in all green plants, algae, and cyanobacteria, it absorbs light in the blue-violet and red regions. Chlorophyll-b: An accessory pigment found mainly in green plants; it helps extend the absorption spectrum of light. Chlorophyll is also used as a natural green dye in the food industry and is known for its detoxifying and antioxidant properties**[2].**

2.2Carotenoids (Yellow, Orange, and Red Pigments)

Carotenoids are a group of pigments responsible for the bright yellow, orange, and red colors found in many plants. They also play a role in photosynthesis by capturing light energy and protecting the plant from oxidative damage caused by UV radiation. Carotenoids are divided into two main types Carotenes: (e.g., β-carotene, found in carrots) are precursors to vitamin A. and Xanthophylls: (e.g., lutein, found in marigolds) contain oxygen and often have antioxidant properties. Carotenoids are essential for human health, contributing to eye health and immune system support**[3].**

2.3Anthocyanins (Red, Purple, and Blue Pigments)

Anthocyanins are a class of flavonoids responsible for the red, purple, and blue colors in many flowers, fruits, and vegetables. Their color changes depending on the pH of the environment, appearing red in acidic conditions and blue in alkaline conditions. Anthocyanins attract pollinators and act as antioxidants, protecting plants from UV damage. These pigments have been linked to several health benefits, including improved cardiovascular health and reduced inflammation**[4].**

2.4Flavonoids (Yellow Pigments)

Flavonoids are a large group of polyphenolic compounds with various biological activities. Some flavonoids, such as flavanols and flavones, provide yellow pigmentation. In addition to their coloring role, flavonoids serve as antioxidants and help protect plants from environmental stress. They also regulate UV filtration and attract pollinators. Flowers: Primroses and chamomile have yellow pigments due to flavones. Fruits: Citrus fruits like lemons and oranges contain flavonoids such as hesperidin and naringenin. Vegetables: Onions and broccoli contain flavanols like quercetin**[5].**

2.5Betalains (Red and Yellow Pigments)

Betalains are water-soluble pigments found in a limited range of plants, replacing anthocyanins in species such as beets and amaranths. They are divided into two groups:Betacyanins: Provide red to purple colors. Betaxanthins: Contribute to yellow to orange hues. Betalains exhibit antioxidant, anti-inflammatory, and antimicrobial properties, making them valuable in the food and pharmaceutical industries**[6].**

2.6Tannins (Brown Pigments)

Tannins are polyphenolic compounds that impart a brownish color to plant parts like bark, leaves, and unripe fruits. They are known for their astringent properties, which help protect plants from herbivores and pathogens. Tannins are widely used in the tanning industry for leather production and as natural preservatives in food. Tannins also have antioxidant and antimicrobial properties and are used in medicine and food preservation**[7].**

3.Applications of natural plant pigments

The versatility and safety of natural plant pigments make them suitable for a wide range of applications in various industries:

3.1Textiles and Clothing

Natural pigments are popular in eco-conscious fashion and textile industries due to their non-toxic properties and vibrant colors. Indigo, obtained from the leaves of the Indigofera plant, and madder root, producing red hues**,** are historically significant pigments used in fabrics.

3.2Food Industry

Many natural plant pigments are used as food colorants and additives, providing both color and health benefits**.** Anthocyanins from berries and hibiscus, and curcumin from turmeric, are widely used in beverages, snacks, and condiments**[8].**

3.3Cosmetics and Skincare

Plant-based pigments are increasingly used in cosmetics and personal care products due to their natural origin and added health benefits. Henna, extracted from Lawsonia inermis, is a well-known example used for hair dyeing and skin decoration.

3.4Pharmaceuticals and Herbal Medicine

Many natural plant pigments exhibit therapeutic properties, promoting their use in herbal medicines and pharmaceuticals. For instance, curcumin has potent anti-inflammatory and antioxidant effects, while anthocyanins help in cardiovascular health by reducing oxidative stress**[9].**

3.5Art and Craft

Artists and traditional craftsmen use natural pigments to create eco-friendly paints, inks, and printed fabrics. This not only promotes sustainable art but also preserves cultural practices **[10].**

3.6Health and Environmental Impact

Natural dyes are non-toxic and safer compared to synthetic dyes, which may contain harmful chemicals like azo compounds. They also degrade easily in the environment, reducing the risk of water pollution associated with industrial dye effluents. Additionally, plant-based pigments, such as curcumin and anthocyanins, offer health benefits due to their antioxidant properties, which help combat inflammation, oxidative stress, and certain chronic diseases **[11].**

4.Turmeric (Curcuma longa)

Turmeric, scientifically known as Curcuma longa, is a rhizomatous herbaceous plant from the Zingiberaceae (ginger) family figure (1.1). It is native to Southeast Asia, particularly India, and has been used for thousands of years as a spice, dye, and medicinal agent. Known for its distinct golden-yellow color and earthy aroma, turmeric has become a significant element in traditional medicine systems such as Ayurveda, Traditional Chinese Medicine (TCM), and Unani. Turmeric is widely cultivated in tropical regions, including India, Indonesia, China, and parts of Africa, making it a globally recognized crop for various industrial and therapeutic applications **[12].**

Figure 1.1 : turmeric plant **[13].**

4.1Chemical composition of turmeric

The vibrant yellow color of turmeric is primarily due to its key chemical component, curcumin, a polyphenolic compound belonging to a class of substances known as curcuminoids , which also includes desmethoxycurcumin and bisdemethoxycurcumin. Curcumin is renowned for its numerous health benefits, acting as an antioxidant, anti-inflammatory, and antimicrobial agent. In addition to curcumin, turmeric contains essential oils such as zingiberene and arturmerone, which contribute to its distinctive aroma and provide additional medicinal properties. Beyond these compounds, turmeric is a nutrient-rich plant that also includes proteins, starch, and minerals, enhancing its overall health benefits. The concentration of curcumin in turmeric can vary significantly based on factors such as the cultivar, growing conditions, and extraction methods used. This variability underscores the importance of proper processing techniques to maximize the health benefits of turmeric and its active compounds**[14].**

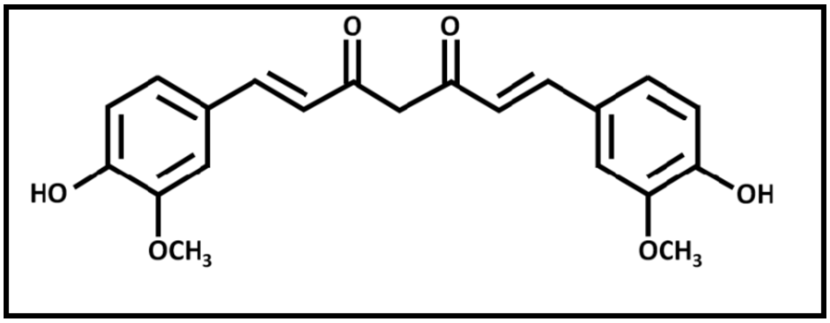

Figure1.2: chemical structure of curcumin

4.2Uses of turmeric

Turmeric is a versatile plant widely used across various industries due to its vibrant yellow color and numerous health benefits. In the dye industry, turmeric's natural yellow pigment is utilized as a textile dye, particularly for cotton and silk fabrics. Although it is not very lightfast and may fade with exposure to light, turmeric remains a popular choice for eco-friendly dyeing practices. Additionally, turmeric serves as a pH indicator; in alkaline solutions, it changes color from yellow to red, making it useful in scientific experiments. In the food and beverage industry, turmeric is recognized as a natural colorant (E100) and is incorporated into a wide range of food products, including processed foods, dairy items, and beverages. Its vibrant hue enhances the visual appeal of these products while providing potential health benefits. Furthermore, turmeric plays a significant role in cosmetics and skincare. Its anti-inflammatory and antioxidant properties make it a sought-after ingredient in various cosmetic formulations. Turmeric is known to help reduce acne, brighten skin, and treat hyperpigmentation, making it popular in face masks and lotions aimed at promoting clear and healthy skin. Overall, turmeric’s multifaceted applications in dyeing, food, and cosmetics underscore its importance as a natural resource in sustainable practices **[15].**

4.3Toxicity of turmeric

While turmeric and curcumin are generally considered safe, excessive consumption or improper use may lead to certain adverse effects and toxicity concerns. High doses of curcumin may cause gastrointestinal discomfort, including nausea, diarrhea, and indigestion. Some individuals may experience allergic reactions, such as skin rashes, when using turmeric topically. Additionally, curcumin has anticoagulant properties, which could increase the risk of bleeding, especially when combined with blood-thinning medications. In rare cases, excessive intake of turmeric supplements may impair liver function or lead to gallbladder problems, particularly in people with pre-existing liver or gallbladder conditions. There is also evidence suggesting that high concentrations of curcumin could interfere with the absorption of iron, which may be a concern for individuals prone to anemia. While culinary use of turmeric is safe for most individuals, it is important to monitor the intake of concentrated curcumin supplements and consult healthcare providers, especially for those with existing health conditions or on medication**[16].**

5.Hibiscus

Hibiscus, particularly Hibiscus sabdariffa, is a flowering plant belonging to the Malvaceae family figure (1.3). It is native to tropical regions of Africa, Asia, and the Caribbean but is cultivated worldwide for its vibrant flowers and culinary uses. Known for its striking red color, hibiscus is often used in teas, beverages, and as a natural dye, and it holds significant cultural and medicinal importance in various traditions.

Figure1.3: Hibiscus plant

5.1Chemical composition of hibiscus

Hibiscus, particularly Hibiscus sabdariffa, boasts a rich chemical composition that contributes to its vibrant color and health benefits. The primary component is anthocyanins, especially delphinidin, which gives the plant its deep red hue. Other important anthocyanins include cyanidin and pelargonidin, known for their antioxidant properties. In addition to anthocyanins, hibiscus contains various flavonoids like quercetin and kaempferol, which have anti-inflammatory effects. The unique flavonoid hibiscetin may offer additional health benefits. The plant also features several organic acids, such as citric and malic acids, contributing to its tart flavor, along with ascorbic acid (vitamin C), which supports immune health. Hibiscus is rich in essential oils like zingiberene and beta-caryophyllene, which provide aroma and potential medicinal properties. Additional components include polysaccharides for soothing effects, saponins for cholesterol reduction, and tannins for astringency. Furthermore, hibiscus is a source of essential minerals (calcium, iron, magnesium, and potassium) and various vitamins, enhancing its overall antioxidant capacity.

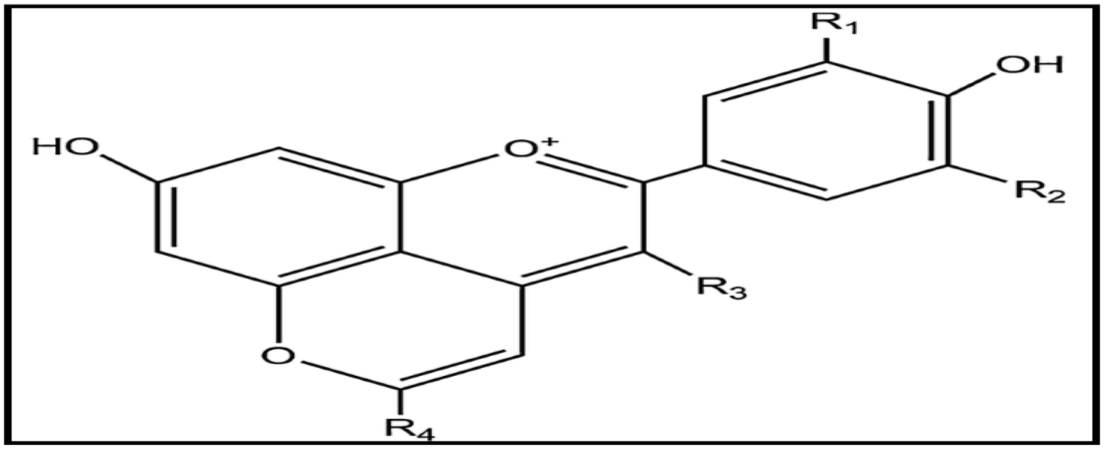

Figure1.4: General chemical structure of anthocyanin

5.2Uses of hibiscus

Hibiscus, particularly Hibiscus sabdariffa, is a versatile plant known for its vibrant red flowers and various applications. Primarily, it is used to make hibiscus tea, a popular beverage enjoyed for its tart flavor and refreshing qualities. This tea is rich in antioxidants and is believed to offer health benefits, such as lowering blood pressure and cholesterol levels. Beyond culinary uses, hibiscus serves as a natural dye, leveraging its bright pigments, mainly anthocyanins, to color textiles, food, and cosmetics. The plant also holds medicinal properties, traditionally used to treat digestive issues, respiratory infections, and skin conditions, thanks to its anti-inflammatory and antimicrobial effects. Overall, hibiscus is celebrated for its culinary, medicinal, and dyeing applications, making it a valuable and multifunctional resource**[17].**

5.3Toxicity of hibiscus

Hibiscus, especially Hibiscus sabdariffa (roselle), is generally safe for consumption and widely used in culinary and medicinal practices. However, moderate intake is recommended, as excessive consumption may cause gastrointestinal issues like gas, bloating, or diarrhea, and rare allergic reactions can occur. Hibiscus has hypotensive effects, which can lower blood pressure, necessitating caution for individuals on blood pressure medications. It may also lower blood sugar levels, potentially interfering with diabetes medications. Pregnant and breastfeeding women should avoid excessive consumption due to limited research on its effects. Additionally, hibiscus contains oxalates, which could contribute to kidney stone formation in susceptible individuals. Some animal studies indicate that very high doses of hibiscus extract may lead to liver toxicity, but this is not typically a concern with normal dietary use. In summary, while hibiscus is beneficial, it should be consumed in moderation, and individuals with specific health concerns or those on medications should consult a healthcare professional before use**[18].**

CHAPTER TWO

Materials and methods

1.Samples preparation

The water extraction method was selected due to its simplicity, non-toxicity, and alignment with green chemistry principles.

1.1Turmeric dye extraction:

2 grams of turmeric were weighed and mixed with 50 mL of water in a beaker. The mixture was then heated on a hot plate for 7 minutes to accelerate the extraction process of the dye from the hibiscus. After heating, the mixture was filtered to separate the colored liquid extract from the solid residue. This filtration step ensured the removal of undissolved plant materials, resulting in a pure turmeric dye extract ready for further analysis.

1.2Hibiscus dye extraction:

2 grams of hibiscus were weighed and mixed with 50 mL of water in a beaker. The mixture was then heated on a hot plate for 7 minutes to accelerate the extraction process of the dye from the hibiscus. After heating, the mixture was filtered to separate the colored liquid extract from the solid residue. This filtration step ensured the removal of undissolved plant materials, resulting in a pure turmeric dye extract ready for further analysis.

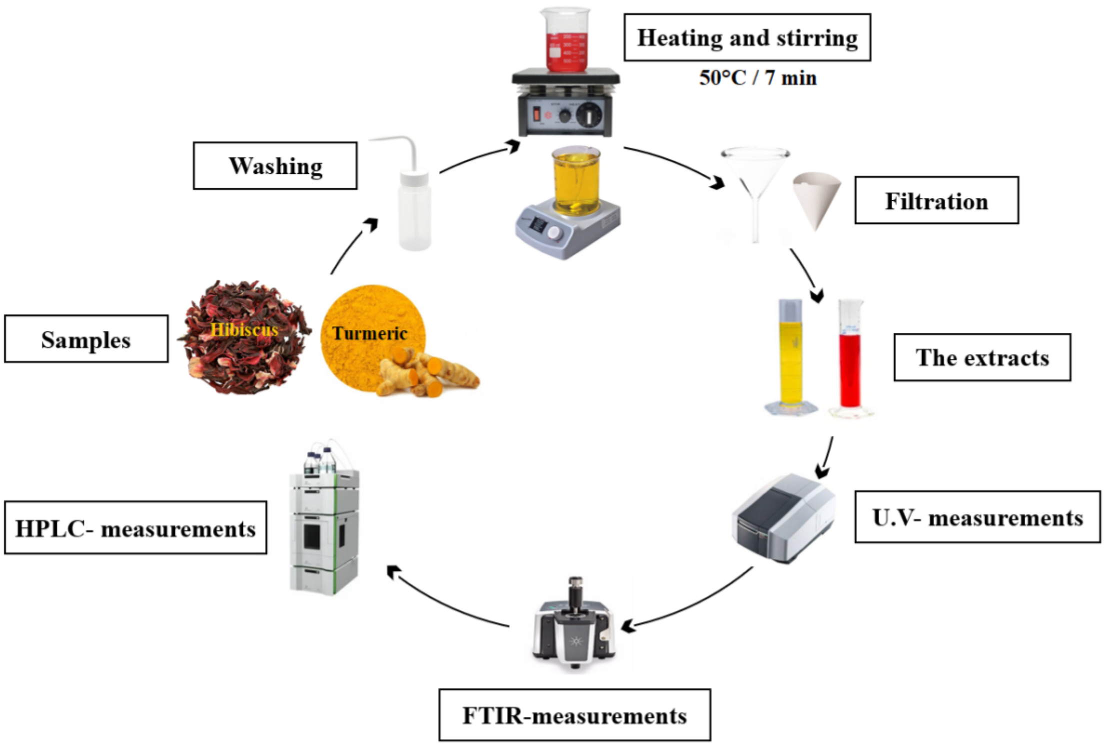

Figure:2.1 Samples preparation and measurements

2.Analytical Techniques

In this study, the UV-Vis Spectrophotometer, FTIR Spectrometer, and HPLC System were employed to analyze and characterize the plant pigments extracted from turmeric (Curcuma longa) and hibiscus (Hibiscus sabdariffa). These techniques provided a comprehensive understanding of the pigments' optical, chemical, and molecular properties, ensuring the accuracy, reproducibility, and reliability of the results. Each technique contributed unique insights into the properties of the plant-based pigments, supporting a holistic evaluation that validates their use for various industrial and scientific applications.

2.1UV-Vis Spectrophotometer

A UV-Vis spectrophotometer is an analytical instrument used to measure the absorption of ultraviolet (UV) and visible (Vis) light by a substance (figure 2.2). It works by passing light through a sample and detecting how much of the light is absorbed at specific wavelengths, typically between 200–800 nm. This instrument is widely used to determine the concentration and structure of organic and inorganic compounds. In the context of plant pigments, UV-Vis spectrophotometry helps identify characteristic absorption peaks different materials. It is an essential tool in chemistry, biology, and pharmaceutical research for studying the optical properties of molecules. The UV-Vis Spectrophotometer was utilized to measure the absorption spectra of the pigments across a wavelength range of 200–800 nm, revealing their characteristic peaks. This technique helped confirm the presence of pigments in crude curcumin and hibiscus. UV-Vis analysis also provided information about the intensity and purity of the extracts, which is crucial for applications in textiles, cosmetics, and food industries. Additionally, the optical properties obtained from this method give insights into color stability and absorption behavior under various conditions**[19].**

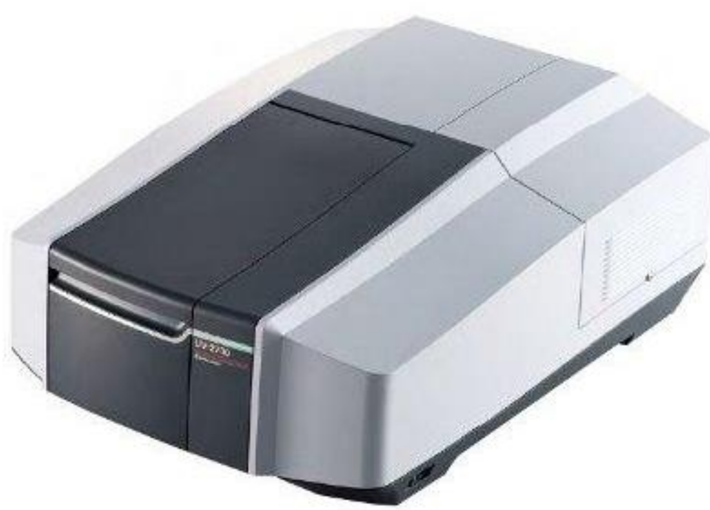

Figure2.2 : UV-Vis Spectrophotometer

2.2Fourier Transform Infrared (FTIR) Spectrometer

An FTIR spectrometer is used to detect the functional groups present in a substance by measuring the absorption of infrared radiation across a range of wavelengths, typically from 4000–400 cm^{-1}. The sample absorbs IR radiation at frequencies corresponding to the vibrations of its molecular bonds, producing a unique spectrum, known as the molecular (finger2.3).This spectrum helps identify chemical structures and interactions. In plant dye analysis, FTIR spectroscopy reveals key functional groups confirming the presence of compounds like curcumin or anthocyanins. FTIR is widely applied in materials science, chemistry, pharmaceuticals, and food analysis to determine chemical composition and purity. The FTIR Spectrometer was employed to identify the functional groups and molecular bonds in the extracted of crude curcumin and hibiscus. It provided detailed spectra showing the vibrations of chemical bonds present in both plants**[20].**

Figure2.3: FTIR Spectrometer

2.3High-Performance Liquid Chromatography (HPLC)

HPLC is a highly precise analytical technique used to separate, identify, and quantify individual components in a mixture. In this system, a sample is injected into a column packed with stationary-phase material, and a solvent (mobile phase) pushes the sample through the column under high pressure. Different components travel at different speeds, allowing for their separation(figure2.4). The output, called a chromatogram, displays peaks corresponding to the individual compounds. In the case of plant pigments, HPLC helps determine the concentration and purity of pigments like curcumin in turmeric and anthocyanins in hibiscus. HPLC is essential in pharmaceuticals, food analysis, environmental testing, and natural product research for precise quantitative and qualitative analysis**[21].**

Figure2.4: HPLC System

CHAPTER THREE

Results and discissions

The UV-Vis analysis of turmeric extract revealed a prominent absorption peak at 310 nm as shown in figure (3.1), confirming the presence of curcumin, the primary pigment responsible for its yellow coloration**.** While, the UV-Vis spectrum of hibiscus dye exhibited peaks around 315 and 524 nm as depicted in(figure 3.2), characteristic of anthocyanins, which contribute to the red-purple color of hibiscus extracts. The peak around 310 nm was related to phenolic and flavonoid compounds. Whereas, the peak around 520-530 nm: Corresponding to anthocyanins, which are responsible for the red-purple coloration. The specific peak can vary slightly based on the solvent and concentration used. These absorption patterns align with previously reported studies, indicating that the extraction process was successful in isolating the desired pigments from both plants**[22].**

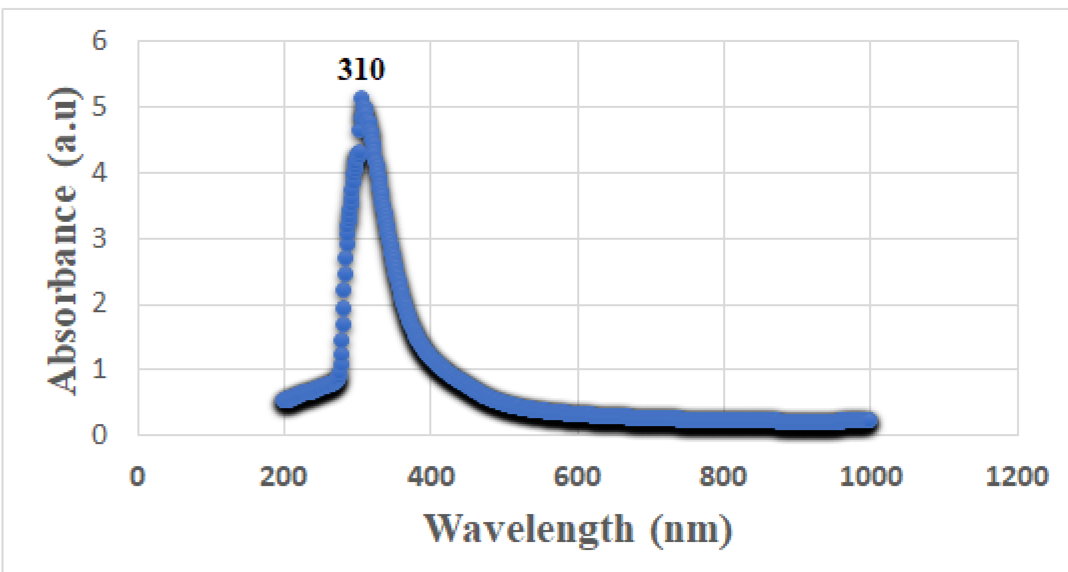

Figure3.1: UV-Vis a spectrum of turmeric extract

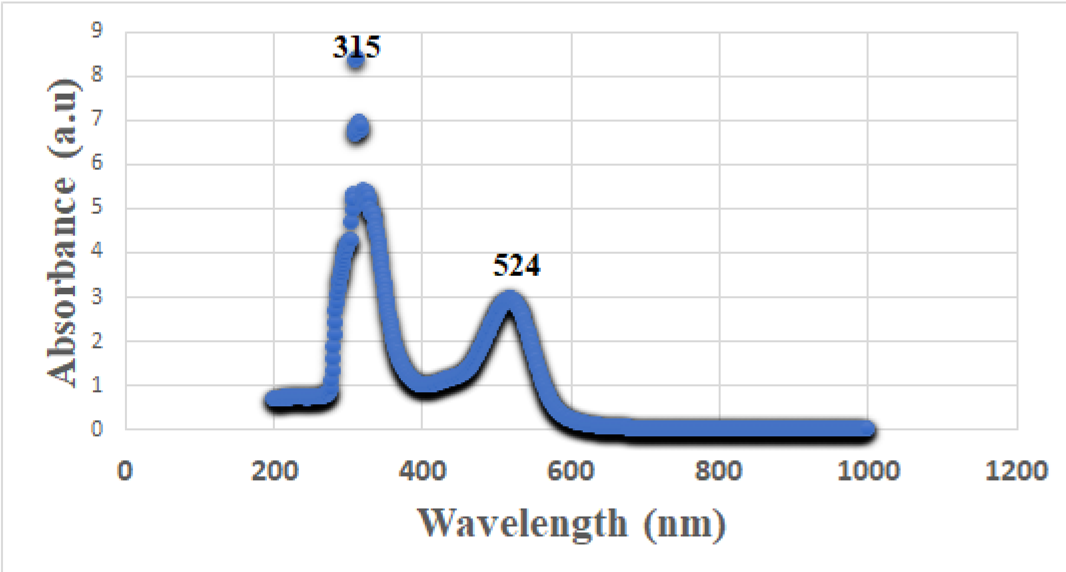

Figure3.2: UV-Vis a spectrum of hibiscus extract

To calculate the band gap (Eg) from UV-Vis absorption peaks, you can use the following formula based on the photon energy**[23].**

$$E_g = \frac{hc}{\lambda}$$

where:

- E_g is the photon energy in eV
- h is Planck's constant $(6.62607015 \times 10^{-34}\ \text{J}\cdot\text{s})$
- c is speed of light $(3.0 \times 10^8\ \text{m/s})$
- λ is the wavelength in meter

$$E_g(eV) = \frac{1240}{\lambda(nm)}$$

Turmeric Extract (310 nm peak):

$$E_g = \frac{1240}{310} \approx 4.00\, eV$$

Hibiscus extract 315 nm peak:

$$E_g = \frac{1240}{315} \approx 3.94\, eV$$

Hibiscus extract 524 nm peak:

$$E_g = \frac{1240}{524} \approx 2.37\, eV$$

These results show that turmeric extract has a higher band gap, while hibiscus extract covers both higher and lower energy regions.

The FTIR spectrum of turmeric extract in figure (3.3) shows key features, including broad peaks in the 3500-3200 cm^{-1} range indicative of hydroxyl groups. A peak around 1650 cm^{-1} suggests carbonyl stretching, likely from curcumin. Additional peaks around 1450-1400 cm^{-1} represent C-H bending, while those in the 1300-1000 cm^{-1} range indicate C-O stretching. Peaks near 800-700 cm^{-1} confirm the presence of aromatic compounds. Overall, the spectrum underscores the rich phytochemical profile of turmeric**[24].**

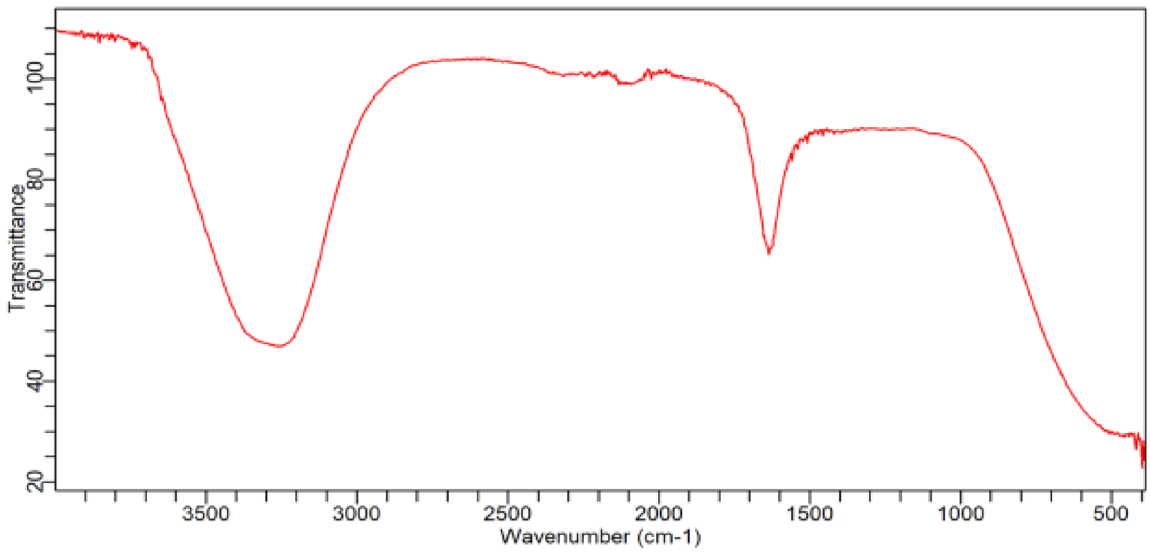

Figure3.3: FTIR spectrum of turmeric extract

The FTIR spectrum of hibiscus extract in figure (3.4) shows several important features. Broad peaks in the region of 3500-3200 cm^{-1} indicate the presence of hydroxyl (-OH) groups, which are common in anthocyanins. A peak around 1650 cm^{-1} suggests the presence of carbonyl (C=O) groups, typical of flavonoids. Additional peaks in the region of 1400-1200 cm^{-1} indicate C-C and C-O stretching vibrations, supporting the presence of aromatic compounds. Overall, the spectrum highlights the phytochemical composition of hibiscus, rich in anthocyanins and other phenolic compounds**[25].**.

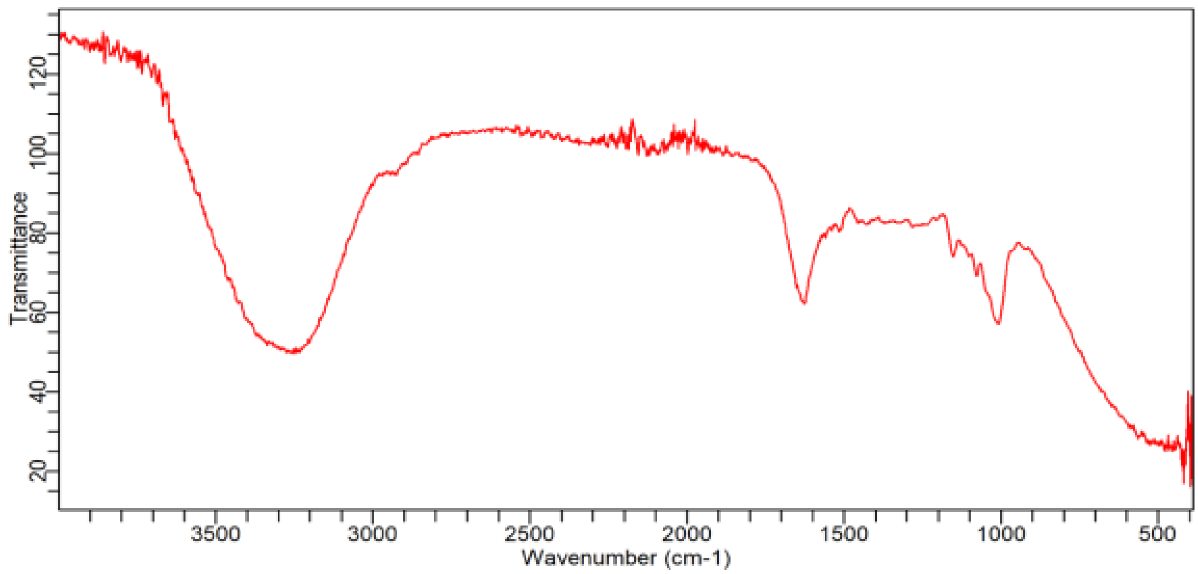

Figure3.4: FTIR spectrum of the hibiscus extract

Feature	Turmeric Extract	Hibiscus Extract	Differences
Broad Peak (3500-3200 cm^{-1})	OH	OH	Similar
Peak (1650 cm^{-1})	Carbonyl stretching (curcumin)	Carbonyl stretching (anthocyanins)	Similar
Peak (1450-1400 cm^{-1})	C-H bending vibrations	C-H bending vibrations	Similar
Region (1000-1100 cm^{-1})	Not present	Specific peak indicating C-O stretching or other compounds	Unique for hibiscus
Peaks (800-700 cm^{-1})	Aromatic compounds	Aromatic compounds	Similar

A qualitative analysis of crude turmeric and hibiscus pigments extracts was performed using a liquid chromatography system. The HPLC chromatograms of both turmeric and hibiscus extracts confirmed the presence of curcumin and anthocyanin retention times 2.5 and minutes respectively. (Figure 3.5 , 3.6) (and respectively). Curcumin and anthocyanins are key pigments responsible for the vibrant colors of turmeric and hibiscus, respectively. In the turmeric extract, a single dominant peak corresponding to curcumin was observed, indicating the efficiency of the extraction method. Similarly, the hibiscus extract displayed multiple peaks, with anthocyanins being the dominant components, reflecting the complex nature of the pigment. These results suggest that both curcumin and anthocyanins can be reliably extracted and purified using this approach, making them viable candidates for use in natural product industries**[26].**

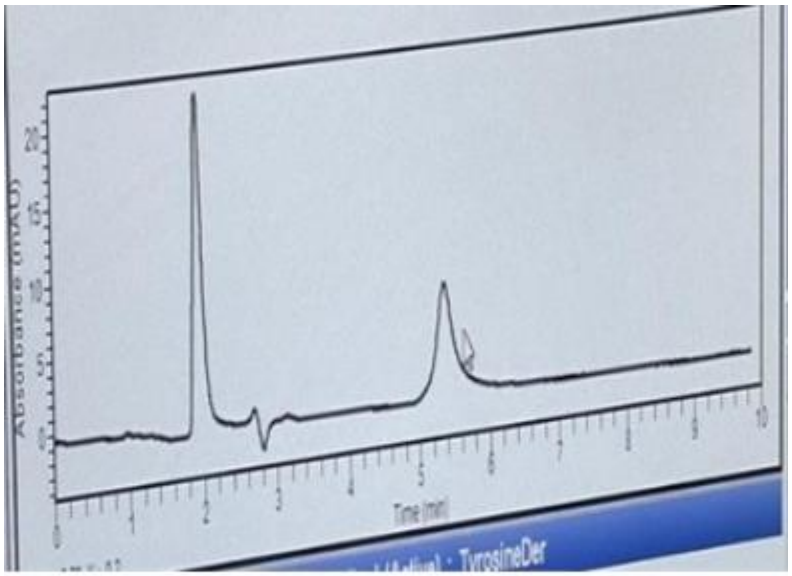

Figure3.5: HPLC Chromatogram of turmeric extracts

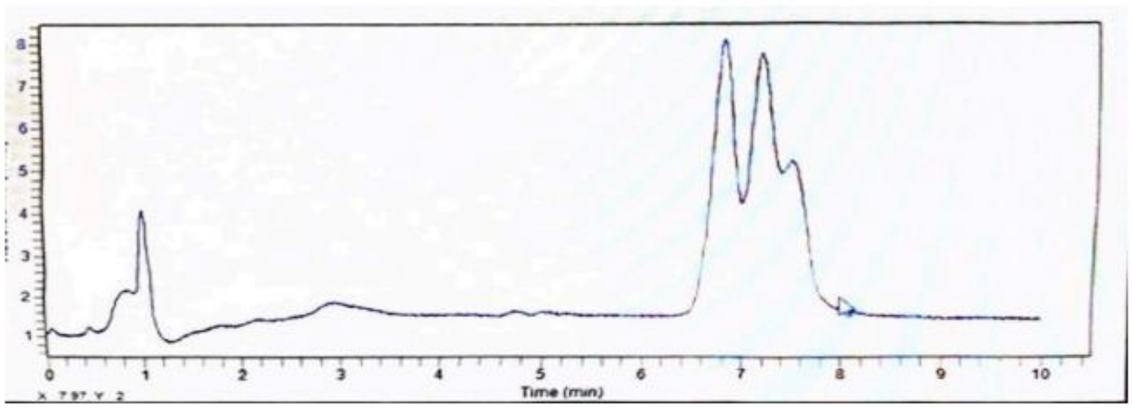

Figure3.6: HPLC Chromatogram of hibiscus extracts

Conclusion

This study concludes that the spectrum patterns of crude pigment extracts from turmeric (Curcuma longa) and hibiscus (Hibiscus sabdariffa) provide substantial insights on their chemical composition and prospective applications. The unique absorption peaks seen in UV-Vis spectroscopy validate the presence of curcumin in turmeric and anthocyanins in hibiscus, corroborating their function as natural colorants. The determined band gap values, almost 4 eV for turmeric and 3.94 and 2.37 eV for hibiscus, suggest favorable potential for these pigments in photonic device applications. Moreover, HPLC and FTIR tests validate the identification of these essential chemicals, underscoring their significance across multiple industries. This research underscores the viability of employing natural plant dyes as sustainable and eco-friendly substitutes for synthetic colors in food, textiles, and cosmetics, promoting the incorporation of these natural resources into contemporary industrial activities.

References

1. **Sharma, R., & Bhat, A. (2021)**. *Plant-Based Natural Pigments: An Eco-Friendly Alternative to Synthetic Colorants*. *Journal of Cleaner Production*, 286, 125457. DOI:10.1016/j.jclepro.2020.125457
2. **Krauss, W. (2017)**. *Chlorophylls and Their Derivatives: A Review of Chemistry and Applications in Food and Health*. *Molecules*, 22(6), 911. DOI:10.3390/molecules22060911
3. **Bhosale, P. (2018)**. *Carotenoids and Human Health: A Review of Their Role in Eye Health and Immune Function*. *Clinical & Experimental Optometry*, 101(3), 233-241. DOI:10.1111/cxo.12757
4. **Harborne, J. B., & Williams, C. A. (2000)**. *Anthocyanins and Flavonoids: Functions and Effects on Human Health*. *Phytochemistry*, 55(6), 781-804. DOI:10.1016/S0031-9422(00)00293-2
5. **Nijveldt, R. J., et al. (2001)**. *Flavonoids: A Review of the Health Effects*. *Food Chemistry*, 78(4), 381-390. DOI:10.1016/S0308-8146(01)00329-2
6. **Strack, D., et al. (2003)**. *Betalains: A New Class of Antioxidants*. *Current Topics in Nutraceutical Research*, 1(1), 1-8. DOI:10.2174/1389201033343977
7. **Sinha, S. K. (2003)**. *Tannins in Human Health and Disease: A Review*. *Journal of Food Science and Technology*, 40(2), 103-106. DOI:10.1007/BF02934202
8. **Pérez-Gálvez, A., & Carretero, M. (2020)**. *Natural Pigments in Food and Cosmetics: Benefits and Applications*. *Critical Reviews in Food Science and Nutrition*, 60(16), 2767-2782. DOI:10.1080/10408398.2019.1633572
9. **Rani, A., & Awan, S. H. (2021)**. *Natural Dyes: A Review of Their Applications in Textile Industry*. *Journal of Natural Fibers*, 18(2), 298-309. DOI:10.1080/15440478.2019.1587154
10. **Baker, A. E., & Abenojar, E. C. (2020)**. *Natural Colorants: Benefits and Applications in the Food Industry*. *Comprehensive Reviews in Food Science and Food Safety*, 19(3), 1142-1165. DOI:10.1111/1541-4337.12530
11. **Khan, M. I., & Anjum, S. (2018)**. *Environmental Impacts of Synthetic Dyes and the Role of Natural Dyes: A Review*. *Environmental Science and Pollution Research*, 25(5), 12345-12357. DOI:10.1007/s11356-018-1345-1
12. **Bhat, K. S., & Bhat, A. S. (2019)**. *Curcuma longa L.: A Comprehensive Review on its Botany, Phytochemistry, and Pharmacological Properties*. *International Journal of Pharmacognosy and Phytochemical Research*, 11(5), 785-796.

13. **Abdel-Hafez, S. M., Hathout, R. M., & Sammour, O. A. (2021).** Attempts to enhance the anti-cancer activity of curcumin as a magical oncological agent using transdermal delivery. *Advances in Traditional Medicine*, 21(1), 15-29. DOI:10.1007/s13596-021-00477-6
14. **Kumar, G. S., & Ranjan, R. (2018).** *Curcumin: A Review on Its Impact in Human Health and Disease*. *Journal of Medicinal Plants Research*, 12(5), 52-59.
15. **Bansal, S., & Bhardwaj, R. (2022).** *Turmeric (Curcuma longa): A Review on Its Applications in Dyeing, Food, and Cosmetics Industries*. *Natural Product Research*, 36(2), 236-250.
16. **Bhardwaj, R., & Bansal, S. (2021).** *Curcumin: A Natural Compound with Diverse Health Benefits and Safety Concerns*. *Current Topics in Medicinal Chemistry*, 21(20), 1818-1836.
17. **Wang, Y., & Xu, M. (2022).** *Hibiscus sabdariffa: Chemical Composition, Health Benefits, and Applications*. *Frontiers in Nutrition*, 9, 852569.
18. **Ali, B. H., & Al Wabel, N. A. (2019).** *Hibiscus sabdariffa: A Review on Its Pharmacological and Nutritional Properties*. *Molecules*, 24(9), 1914.
19. Ranjbar, B., & Sadeghi, N. (2017). UV-Vis Spectrophotometry: A Powerful Tool for the Analysis of Organic Compounds. *Chemistry Research Journal*, 2(1), 1-12.
20. C. R. (2016). Fundamentals of Fourier Transform Infrared Spectroscopy. *Journal of Chemical Education*, 93(12), 2057-2064. doi:10.1021/acs.jchemed.6b00424.
21. R. M., & S. A. (2018). Application of HPLC in the Analysis of Natural Products. *Molecules*, 23(5), 1216. doi:10.3390/molecules23051216
22. **Khan, M. I., & Khattak, K. F. (2020).** *Spectroscopic and Antioxidant Studies of Curcumin from Turmeric and Its Potential Applications in Food Industry*. *International Journal of Food Properties*, 23(1), 1390-1401.
23. **R. A. Marcus and N. S. Ginsberg**, “Theoretical Basis for UV-Vis Absorption Spectroscopy and Its Application to the Study of Band Gap Energies of Nanomaterials,” *The Journal of Physical Chemistry C*, vol. 118, no. 35, pp. 19752-19765, 2014. DOI: 10.1021/jp5059382.
24. **K. M. S. A. Al-Sabagh, M. H. Abd El-Aziz, and M. H. Z. Abd El-Monem**, “Fourier Transform Infrared Spectroscopy (FTIR) Studies on Curcumin Derivatives and Their Biological Activity,” *International Journal of Biological Macromolecules*, vol. 142, pp. 446-454, 2020. DOI: 10.1016/j.ijbiomac.2019.09.207.
25. **A. A. K. Al-Yahya, A. M. Al-Massarani, and M. F. M. Almalki**, "Spectroscopic Characterization of Hibiscus sabdariffa Extract and Its Antioxidant Activity," *Saudi Journal of Biological Sciences*, vol. 26, no. 6, pp. 1520-1526, 2019. DOI: 10.1016/j.sjbs.2019.06.001.

26. **N. Choudhury, S. Kumar, and S. Gupta**, "HPLC Analysis of Curcumin and Anthocyanins from Natural Sources," *International Journal of Pharmacognosy and Phytochemical Research*, vol. 8, no. 2, pp. 255-262, 2016. DOI: 10.25258/phyto.v8i2.6724.