

Characterization of Natural Dye Extract obtained from Almond Leaves

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Abstract

The aim of this study is to characterize natural dye extract obtained from almond leaves. The study was carried out by extracting dye from almond leaves using ethanol and soxhlet apparatus. Uv-spectrophotometer, FTIR, atomic absorption, thermogravimetric and GC/MS analyses were performed on the dye extract. Several bioactive compounds and functional groups were identified. The uv-spectrophotometer analysis results reveal the presence flavonoids compounds and functional groups through the absorbance peaks. FTIR analysis results also reveal several peaks with corresponding functional groups such as HO, C=O, C=C, N-H, >N-N, >C-, among others. TGA/DTA results reveal two stages of thermal degradation of the dye extract, which correspond to dehydration or evaporation of volatile compounds and decomposition of the dye extract with exothermic decomposition. The results for atomic absorption spectroscopy analysis reveals the presence of chromium, cadmium, iron, lead, nickel, mercury, zinc and copper in the dye extract at traceable amount. The GC/MS analysis results reveal several peaks corresponding to about eighty one bio-compounds which are identified by comparing their retention time and mass spectra with the NIST and Wiley libraries. Those identified compounds are found to belong to alkaloids, flavonoids, steroids, aromatic, acid, sugar, ester, nitro, terpenes, ketone, carotene, aldehyde, silicone compounds which make the dye extract as an alternative to synthetic dyes applied in coloring textiles.

Key words: Natural dye, Almond leaves, Characterization, Bioactive, Extraction

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I. Introduction

Plants contain many biochemical compounds such as saponins, steroids, alkaloids, flavonoids, phenols, terpenoids and tannins, which have medicinal properties such as anti-microbial, anti-bacterial, anti-oxidant, anti-cancer, anti-inflammation among others (Fasya, Baderos, Madjid, Amalia and Megawati, 2021). These biochemical compounds are the secondary metabolites that are not directly involve in the growth and development of the plants but, they are evolutionary defense which is built up in the plants (Ahuchaogu et al, 2018; Macia, Garcia and Vidaure, 2005). The most noticeable secondary metabolites found in plants are the phenolic compounds containing several benzene rings, with one or more hydroxyl group. This group of compounds varies from simple phenolic molecules to highly polymerized compounds. The polyphenol compounds contain quite a few ranges of compounds like simple flavonoids, complex flavonoids, colored anthocyanins and phenolic acid compounds. These have been reported to show a positive impact due to their antioxidant activity and, also indicating inhibition of α -glucosidase and α -amylase and assist in the curing of typy-2 diabetes (Heima, Tagliaferroa and Bobilya, 2002; Kumarmath, Kawatal and Nimbargi, 2022). The chemical structures of secondary metabolites and the chromophores present in dye molecules can provide useful information concerning the activities of compounds present in dye extracts of plants. The chromophore is the conjugated system portion of the molecule that is responsible for absorption of UV or visible radiation (Obaseki, Olugbuyiro, De, and Kesinro, 2017).

Heavy metals are characterized to possess high density and atomic weight, and the majorities of them are found in the biosphere, such as in water, soils, and rocks (Azeh, Udoka, Nweke, Unachukwu, 2019; Mitra et al 2022). They are released into the environment from anthropogenic resources, mostly commercial and industrial places. Among these heavy metals are chromium, cadmium, manganese, iron, copper, zinc, thallium, antimony, cobalt, nickel, lead and mercury and, they have been identified to possess toxic properties which are harmful to living organisms ((Coetzee, Bansal and Chirwa, 2020; Rice, Walker, Wu, Gillette, Blough, 2014). Though, reports from recent research works have indicated that some of them are useful to human beings and widespread in nature among them being zinc, copper and nickel. The natural existing ones are vital, and penetrate into the plant and animal bodies through air, food and water, and usefully control numerous biological

activities (Chasapis, Loutsidou, Spiliopoulou, Stefanidou, 2012; Elgarahy, Elwakeel, Mohammad and Elshoubaky, 2021; Roohani, Hurrell, Kelishadi, Schulin, 2013)

The almond tree is also known as Indian almond, country almond sea almond, almond Malabar or tropical almond, belonging to Combretaceae family. The tree commonly grows in tropical regions and is prominently found in Africa, Asia and Australia. It has been reported that it is one the promising resources in which natural dye can be obtained in order to substitute that of synthetic dyes. The leaves of the plant are large up to 15–25 cm (5.9–9.8 inch) long and 10–14 cm (3.9–5.5 inch) wide, ovoid, glossy dark green, and leathery (Kumarmath et al, 2022; Ibrahim, Keturah, Lydia, Appollm, Ibrahim, 2021).

Fabrics worn on bodies are always in contact with the skin of which there is the possibility of exchange of fluids that are capable of conveying useful and harmful substance in and out of the body. They provide adequate protection to the body with suitable temperature, dehydration, absorbing sweat, however, facilitating the growth of pathogens. The grown pathogen can accumulate on both the fabrics and human skin which would result to unbearable infectious diseases and odor on both the skin and the fabric (Gutarowska, Pietrzak, Machnowski and Milczarek, 2017). In addition, the micro-organisms which grow on the fabrics are also potent enough to deteriorate the fabric and its colors. Therefore, natural dyes with their bioactive compounds can provide protection against the microbial activities on textiles beside their color. Moreover, non-carcinogenic, non-allergy, non- toxicity, anti-bacterial activity, antioxidant activity and anti-inflammatory activity of textiles are the indispensable recommendations for medical application, and other field of endeavor (Li, Liu, Li, and Wang, 2012; Zhou, Yang, and Tang, R, 2020). This study is carried out to characterize natural dye extract obtained from almond leaves using.

II. Material and method

Materials

Mortar, pestle, almond leaves, bowls, sieve, soxhlet apparatus, buckets, weigh balance, thermometer, spatula, conical flask, desiccator, measuring cylinder, ethanol and Gas Chromatography/Mass spectrometer.

Methods

Soxhlet Extraction

The almond leaves were collected from Federal Polytechnic, Nasarawa premises, dried in an open shade to avoid the sun's Uv-radiation from damaging the leaves, and then grinded in a mortar with pestle. The grinded leaves were sieved to obtain almond leaves powder. Solvent extraction was performed on the powder using soxhlet apparatus and ethanol. A mixture of dye extract and ethanol obtained from the extraction was subjected to distillation in order to recover the solvent from the mixture. The dye extract was finally obtained by keeping the extract inside an oven at 65°C and desiccator.

Uv-Visible Spectrophotometer

The biochemical components and functional groups of the dye extracts of almond leaves were determined by using Shimadzu Uv-visible spectrophotometer (1800-series). The analysis was carried out by weighing 0.15mg of the dye extract and then dissolved in 3ml of distilled water. The solution was then poured into quartz cuvette and scanned from 200nm to 500nm, while distilled water was used as blank.

Fourier Transform Infrared Spectroscopy (FTIR) Analysis

The dye extract obtained from almond leaves was characterized to identify functional groups using FT-IR spectroscopy (Buck Scientific, Model M530 USA). The FT-IR absorption spectroscopy was based on the absorption of IR radiation by molecules of the sample and was most widely used for the identification of the functional groups and organic compounds (Neha and Vidya, 2013). The spectroscope was applied by turning on the instrument and allowing it to stabilize for 30 min, and ensuring that the detector (DTGS/KBr) was cooled. About 1–2 mg of the dye extract was grinded with potassium bromide (KBr) in a ratio of 1:100 and compressed it into a thin pellet in order to avoid moisture absorption. The pellet was the placed in a pellet die, 10 tons pressure was applied on it for 2-3 minutes under vacuum. Then, the formed transparent pellet was stored in a desiccator. The pellet was then transferred into the sample holder and scanned between wavelengths of 4000cm⁻¹–400cm⁻¹ with 4cm⁻¹ resolution, and the spectrum was recorded (Silverstein et al., 2014; Coates, 2006). During the analysis, the organic compounds and functional groups were sensed by interaction between chemical species, functional groups of chemical compounds and electromagnetic radiation (Chairat, Bremmer and Chantrapromma, 2007; Sawiros and Amare, 2023). The spectrum was saved in SPA format. The spectra peaks of the result obtained were then compared with reference spectra to identify the corresponding species.

Atomic Absorption Spectroscopy Analysis

The presence and quantity of heavy metals such as Iron (Fe), Nickel (Ni), Zinc (Zn), Cadmium (Cd), Mercury (Hg), lead (Pb), Copper (Cu) and Chromium (Cr) (Saravanan and Chandramohan, 2011) in almond leaves were investigated using Buck Scientific model 210 VGP of Atomic absorption Spectrophotometer. The analysis involves using 0.5g of dye extract sample and then put into a Teflon digestion tube to which was added 10ml of HNO₃ (65%) and 2ml of HClO₄ (70%) for total digestion. The sample was re-digested at room temperature for 1 hour to avoid violent reaction. Digestion was then carried out by heating the sample at 200°C on a digestion block until fumes cleared (2-3hrs). The heated sample was then cooled, diluted to 50ml with deionized water and filtered (0.45µm) (APH, 2017). Elemental heavy metals were analyzed by installing appropriate hollow cathode lamp (HCL) with optimize lamp current and slit width per manufacturer guidelines. Calibration standard of 0, 1, 2, 5, 10ppm were prepared in 2% HNO₃ and ran calibration curve (R² must be > 0.995) (Welz and Sperling, 2008). After the preparation, the sample was introduced into an apparatus by means of a nebulizer and ran under recommended conditions of air-acetylene flame set flow rates of Air (10L/min, and Acetylene 2.5L/min). Furnace Program: Drying (110°C, 30s) → Pyrolysis (500°C, 20s) → Atomization (1800°C, 5s) using matrix modifiers (e.g., NH₄H₂PO₄ for Pb, Pd(NO₃)₂ for Cd) with injection of 20 µL sample + 5 µL modifier into the graphite tube (EPA Method 7000B, 2007) and run in triplicate and took average readings.

Thermogravimetric Analysis (TGA) and Derivative Thermogravimetry (DTG)

The dye extract was characterized by Thermo-gravimetric analysis (TGA) in order to evaluate the thermal degradation of the dye sample and its stability using TGA4000 PerkinElmer. About 12.212mg of almond leaves dye extract was measured and put into sample holder and then placed in the analyzer chamber and covered. During the analysis, the sample almond dye extract was heated from 30-950°C at 10°C/min in nitrogen atmosphere with a purge rate of 20mL/minute. As the temperature continued to increase as the heat was applied over time, the mass of the decomposed sample was continuously recorded and displayed on a computer screen.

Gas Chromatography/Mass spectrometer (GC/MS) Analysis

Gas Chromatography/ Mass spectrometer analysis was performed on the dye extract obtained from almond leaves in order to identify the organic constituents of the leaves using an Agilent 5977A MSD coupled with a 5890B GC (Agilent Technologies, USA). The GC was equipped with an HP-5MS column (30 m × 0.25 mm × 0.25 µm). The oven temperature was set as follows: initial temperature of the system was 50°C (held for 2 minutes), increased to 300°C at 10°C/min, and held for 10 minutes (Adams, 2007). The injector temperature was set at 250°C, and helium was used as carrier gas at a flow rate of 1 mL/min. The MSD was operated in electron ionization (EI) mode at 70 eV, with a scan range of 40–600 m/z. The dye extract of 1 mg was dissolved in 1 mL of methanol and filtered through a 0.22 µm PTFE syringe filter. Then, 1 µL of the sample was injected in split mode (split ratio 10:1). The corresponding compounds of the peaks were identified by comparing their retention time and mass spectra with the NIST and Wiley libraries (McLafferty and Stauffer, 1989; Thamer, 2023).

III. Results and Discussion

Results for the Uv-visible Spectrophotometer Analysis for Almond Leaves

In spectrophotometer analysis the spectrum of electromagnetic radiation is used to analyze the chemical species of compounds and examine their interaction with electromagnetic radiation. The result in Figure 1 shows the ultraviolet absorption spectra of almond leaves dye extract, and the spectra reveals three absorbance bands of high and low intensities. In addition, six absorbance peaks of wavelength 211nm, 231nm, 274nm, 298nm, 321nm and 388nm were revealed. Obaseki et al (2017) presents that flavonoids exhibit two characteristic UV absorption bands with maxima from 240nm to 285nm and 300nm to 550 nm ranges in a standardized UV-Vis spectroscopy; and anthraquinone compounds absorbance band between 220nm-350nm range. The wavelength between 200nm-300nm indicated the presence of conjugate compounds (LibreTexts, 2025). In view of these, the dye extract of almond leaves contains flavonoids and anthraquinones. In addition, the absorbance peak of 274nm within the very strong band absorption maximum 270 and 295 confirms the presence of flavanones. Absorbance peak between 240-280nm regions is due to the presence of benzoyl system of A- ring flavonoids. The absorbance peaks 321nm and 388nm close to absorbance band between 320nm and 385nm indicates the presence of flavones and flavonols B-ring absorption (Kumar and Pandey, 2013). The peak 231nm may indicate the presence of azido whose absorption band is 230nm, in the dye extract. The absorbance band above 210nm signifies the presence of compound α, β-unsaturated ketones diene, or polyene (Agilent Trusted Answer, 2021; Donald, Gary, George and James 2001, Restiani and Asep, 2022). The five strong absorbance peaks of 211nm, 231nm, 274nm, 298nm and 321nm in the two absorption regions confirm that the

dye extract of almond leave have inherent UV-absorption strength with potential as UV protective agent. So, the dye extract of almond leave can increase the UV- protective property of textile fabrics (Yuyang, Zhi-Yi, and Ren-Cheng, 2020). Furthermore, from the absorbance peaks reveal, the absorbance peak maxima within 178-225nm, 186-280nm and 300-665nm; 230nm may indicate the presence of alkyne, carbonyl, nitroso and aniline in the dye extract respectively (Restiani and Asep, 2022).

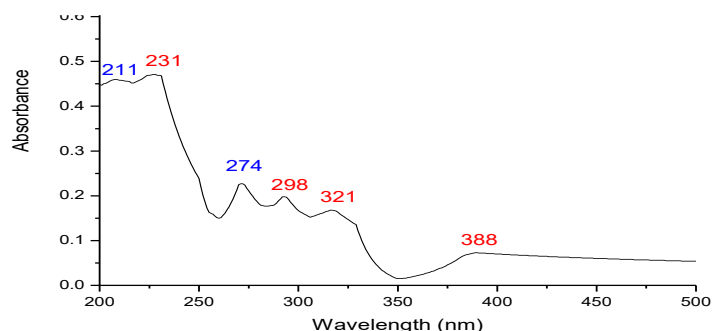


Figure 1: Uv-spectral for ethanol dye extract of almond leaves

Result for FTIR Analysis of Almond Leave Dye Extract

This analysis mostly reveals the functional groups of organic compounds. The results shown in Figure 2 reveal several peaks for the functional groups of the dye extract of almond leaves. Absorbance peak 3769.69cm^{-1} does not correspond to any functional group. The absorbance peak at 3439.43cm^{-1} indicates the existence of heterocyclic amine $>\text{N-H}$ stretch (Muhammadu et al, 2017) and hydroxyl group (H-bond OH stretch) (Yogesh and Namrita, 2017), peak at 3266.33cm^{-1} suggests the presence of ammonium ion (NH_4^+) and normal 'polymeric' OH stretch, peak at 2963.22cm^{-1} indicates the presence of methyl C-H asymmetry/symmetry stretch (Herry et al, 2019). Absorbance at peak 2383.11cm^{-1} corresponds to triple bonds such as ethyne ($\text{C}\equiv\text{C}$) stretch and nitriles ($\text{C}\equiv\text{N}$) stretch species. The absorption band at peak 1731.21cm^{-1} suggests the presence of ester (conjugated), aldehyde (saturated) strong, and ketone (saturated) strong. The absorption band at peak 1636.61cm^{-1} accounts for the presence of alkenes $\text{C}=\text{C}$ (saturated), (conjugated) stretch; primary amine N-H bend, secondary amine, $>\text{N-H}$ bend; amide $\text{C}=\text{O}$ strong; quinone or conjugated ketone; open-chain imino, $-\text{C}=\text{N}-$, and organic nitrates. Absorption band at peak 1475.06cm^{-1} accounts for methylene, C-H bend; carbonate ion, and aromatic rings, $\text{C}=\text{C}-\text{C}$ stretch (medium and weak). Peak at 1367.14cm^{-1} was found to correspond with gem-dimethyl or "iso"- (doublet), carboxylate (carboxylic acid salt), aliphatic nitro compounds NO_2 , nitrate ion. Absorption band at 1206.26cm^{-1} peak confirms the presence of skeletal C-C vibrations, aromatic C-H in-plane bend, tertiary amine CN stretch and aromatic phosphates (P-O-C stretch). Absorption band at peak 1075.35cm^{-1} informs about the existence of aliphatic or aryl fluoro compounds, C-F stretch; alkyl-substituted ether C-O stretch, cyclic ethers, large rings, C-O stretch, primary amine, CN stretch, organic siloxane or silicone (Si-O-Si) (Si-O-C), phosphate ion and silicate ion. Absorption band at peak 814.15cm^{-1} indicates the presence of aromatic C-H out-of-plane bend, C-H 1,4-disubstitution (para), epoxy, and oxirane rings. Absorption band at frequency 690.70cm^{-1} confirms aliphatic or aryl bromo compounds, C-Br stretch, thiol or thioether, CH_2-S (C-S stretch), aryl thioethers, O-S (C-S stretch), and disulfides (C-S stretch), and absorption band at peak 600 cm^{-1} confirms aliphatic iodo compounds, and C-I stretch, disulfides (S-S stretch) (Asep, Rosi, and Risti, 2019; Chem.libretexts.org, nd).

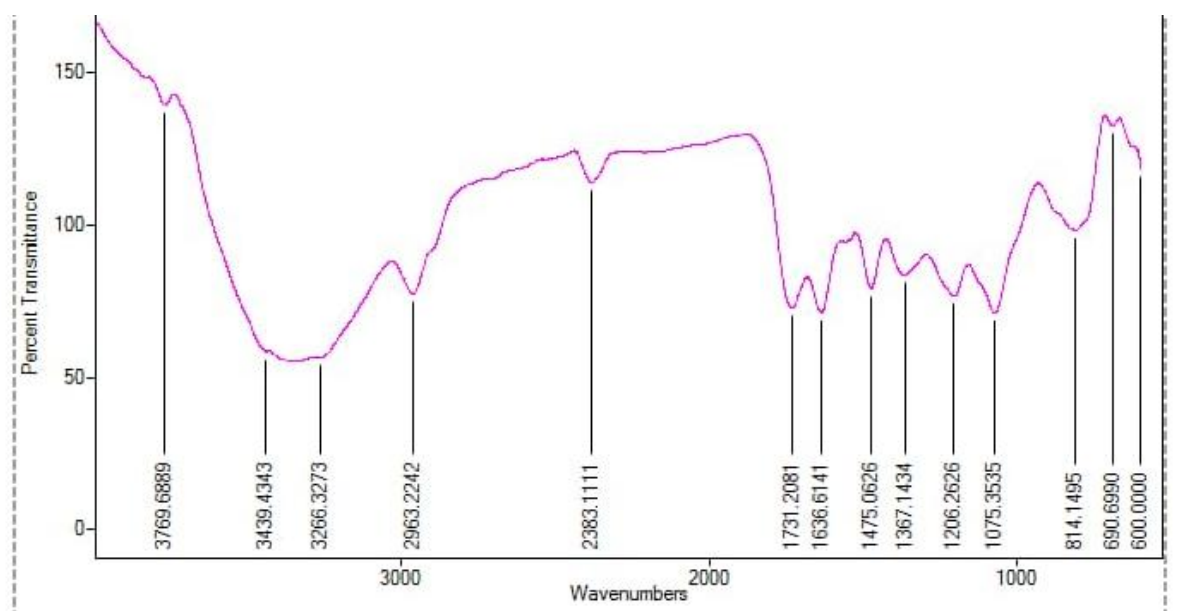


Figure 2: Results for FTIR analysis of almond leaf dye extract

Results for Atomic Absorption Spectrophotometer Analysis (AAS) for Determining the Presence of Heavy Metals in the Dye Extract

Heavy metals are usually referred to as those metals which possess a specific density that is more than 5 g/cm³ and have potential adverse effect on environment and living organisms. But, those metals are generally essential to maintain various bioactive and physiological functions in living organisms when they are in a very low concentration, and they become poisonous and deadly when they exceed certain limit concentrations (Jaishankar, Tseten, Anbalagan, Mathew and Beeregowda, 2014; Saikat et al, 2022). The results in Table 1 reveal the presence and amount of chromium, cadmium and iron in the ethanol dye extract obtained from almond leaves. The results further indicate that the dye extract contains averagely 0.839, 0.184 and 3.15 mg/kg concentration of chromium, cadmium and iron respectively. Table 2 reveals the presence of zinc, copper and nickel metals in the dye extract with average quantity of 4.325, 0.252 and 0.46 mg/kg concentration respectively. Table 3 reveal the presence and amount of lead and mercury metals in the dye extract with average quantity of 0.547mg/kg and 4.60 µg/kg concentration respectively. In this study, low concentrations of heavy metals are found in the dye extract except iron and mercury whose concentrations are averagely high (Elgarahy et al, 2021; Pehlic, Nanic, Jukic, and Aldzic, 2019).

Table 1: Results for Atomic Absorption Spectroscopy of Heavy Metals (Chromium, Cadmium and Iron)

Heavy Metals in Almond Leaves Dye Extract									
	Chromium			Cadmium			Iron		
Sample	Sample weight	Conc mg/kg	Mean	Sample weight	Conc mg/kg	Mean	Sample weight	Conc mg/kg	Mean
A1	0.3982	0.995		0.3982	0.241		0.3982	3.315	
A2	0.4974	0.996	0.839	0.4974	0.200	0.184	0.4974	2.960	3.15
A3	0.6320	0.527		0.6320	0.100		0.6320	3.175	

Table 2: Results for Atomic Absorption Spectroscopy (Zinc, copper and nickel)

Heavy Metal in Almond Leaves Dye Extract									
	Zinc			Copper			Nickel		
Sample	Sample weight	Conc mg/kg	Mean	Sample weight	Conc mg/kg	Mean	Sample weight	Conc mg/kg	Mean
A1	0.3982	4.249		0.3982	0.236		0.3982	0.038	
A2	0.4974	4.387	4.325	0.4974	0.241	0.252	0.4974	0.045	0.046
A3	0.6320	4.338		0.6320	0.278		0.6320	0.054	

Table 3: Results for Atomic Absorption Spectroscopy (Lead and Mercury)

Sample	Lead		Mercury ($\mu\text{g/kg}$); Colorimetry (Lamotte Smart3)				
	Sample weight	Conc mg/kg	Mean	A	B	C	Mean
A1	0.3982	0.649		4.77	4.57	4.446	4.60
A2	0.4974	0.687	0.547				
A3	0.6320	0.305					

Results for TGA/DTA Analysis

The results presented in Figure 3a,b show that the thermogravimetric analysis (TGA) and the derivative thermogravimetric analysis (DTA) for the dye extract obtained from almond leaves, and its entire thermal decompositions occurred between the temperature range of about 29.27 to 918.1°C. The results reveal the behavior of the dye extracts when they were subjected to thermal degradation. Their first derivative (DTA) serves as a mathematical tool applied in combination with TGA to get more accurate information about what happens to the dye extract samples while it is subjected to heat by the gradual increase in temperature and also with respect to time. Figure 3a reveals two stages of degradation that occurs on TGA graph. The first stage indicates a weight loss of about 8% at a temperature range of about 29.27 to 120°C which corresponds to disintegration of volatile compounds or dehydration of the sample. The second stage indicates a weight loss of about 82% at 120 to 918.1°C for the dye extract. The most prominent mass loss by the sample in the second thermal stage as shown in the thermogram of TGA commences at a temperature range close to 200°C with a maximum exothermic peak at about 270°C on DTA curve which may correspond to the beginning of the thermal decomposition of the dye extract. Sample chemical constituents of the dye extract, with intense losses, until almost the entire consumption of the sample close to 550°C to 918.1°C which may correspond to inorganic compounds in the dye extract as shown in Figure 3b (Jade, Rafaela, Carolina, Bárbara and Orquídea, 2023).

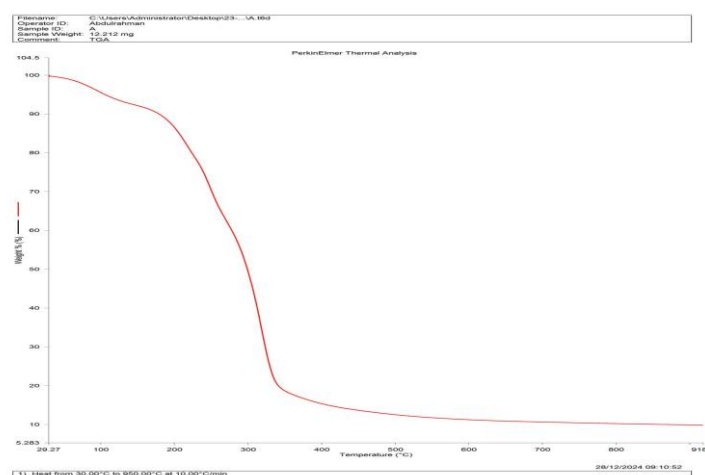


Figure 3a: Result for Thermagravimetric (TGA) analysis

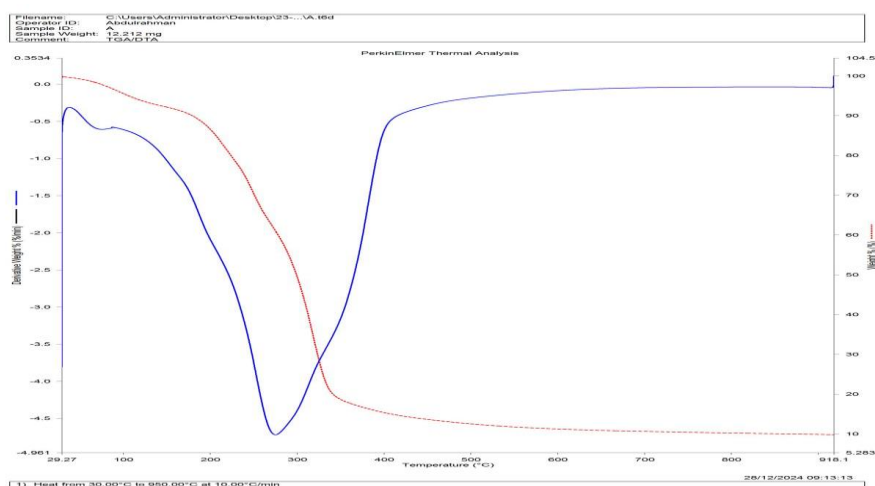


Figure 3b: Result for Derived Thermogravimetric (TGA/DTA) analysis

Results for GC/MS analysis

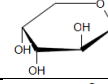
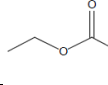
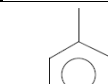
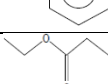
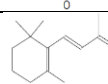
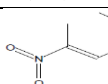
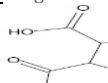
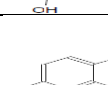
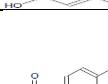
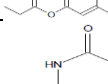
The chromatogram of the GC/MS analysis for ethanol dye extract of the almond leaves in comparison with those of the NIST and Wiley library data reveal a range of about eighty one peaks indicating the presence of eighty one organic compounds in the ethanol dye extract obtained from almond leaves. The large compound fragments into small compounds gives rise to appearance of several peaks at different m/z ratios. The mass spectrometer analyzes the compounds eluted at different times by identifying the nature and chemical structures of the compounds. The mass spectra are fingerprint of the compounds which are identified from the data library. The major identified compounds with their retention times, area sum %, molecular formulas, molecular weights, library and compound groups are shown in Table 4. The entire bioactive compounds separated and identified are D(-)-Lyxose, C₅H₁₀O₅; Pentane, 1-(1-ethoxyethoxy)-, C₉H₂₀O₂; 3-Heptanol, 3,5-dimethyl-, C₉H₂₀O; Tetramethylarsonium, C₄H₁₂As; 2-Deoxy-D-ribose, C₅H₁₀O₄; Pentanoic acid, 4-methyl-, ethyl ester, C₈H₁₆O₂; α,β -Methyl-2-deoxy-D-ribosepyranoside C₆H₁₂O₄; Pentanoic acid, 3-methyl-, ethyl ester, C₈H₁₆O₂; Benzene, 2-ethyl-1,4-dimethyl-, C₁₀H₁₄; Benzene, 1-methyl-3-(1-methylethyl)-, C₁₀H₁₄; Benzene, 2-ethyl-1,3-dimethyl-, C₁₀H₁₄; 1,3,8-p-Menthatriene, C₁₀H₁₄; Dodecanoic acid, ethyl ester, C₁₄H₂₈O₂; Nonanoic acid, ethyl ester, C₁₁H₂₂O₂; Decanoic acid, ethyl ester, C₁₂H₂₄O₂; Octanoic acid, ethyl ester, C₁₀H₂₀O₂; 15-Deoxy-.DELTA.12,14-prostaglandin J₂, C₂₀H₂₈O₃; 1,5-Diphenylhex-3-ene, C₁₈H₂₀; 6-Ketoprostaglandin, C₂₀H₃₂O₆; 5,10-Pentadecadiyn-1-ol, C₁₅H₂₄O; 15(S)-Hydroxy-(5Z,8Z,11Z,13E)-eicosatetraenoic acid, C₂₀H₃₂O₃; Cholecalciferol, C₂₇H₄₄O; Naphthalene, 1,2,3,4-tetrahydro-1,1,6-trimethyl-, C₁₃H₁₈; 2-Ethyl-4-hydroxy-5-methyl-3(2H)-furanone, C₇H₁₀O₃; 1-Acetyl-2-isopropyl-3-methyl-5-hydroxypyrazolidine, C₉H₁₈N₂O₂; 2-Pentenoic acid, 4,4-dimethoxy-, methyl ester, (E)- C₈H₁₄O₄; Naphthalene, 1,2,3,4-tetrahydro-1,6,8-trimethyl-, C₁₃H₁₈; Benzene, 2-(2-butenyl)-1,3,5-trimethyl-, C₁₃H₁₈; 2,2,4-Trimethylchromene-3, C₁₂H₁₄O; Fenfluramine, C₁₂H₁₆F₃N; 2-Methylglutaric acid; C₆H₁₀O₄; 2,4,7,9-Tetramethyl-5-decyne-4,7-diol, C₁₄H₂₆O₂; trans-2-Dodecen-1-ol, C₁₂H₂₄O; Undecanedioic acid, C₁₁H₂₀O₄; Undecanoic acid, ethyl ester, C₁₃H₂₆O₂; Octadecanoic acid, ethyl ester, C₂₀H₄₀O₂; Undecanoic acid, 2,8-dimethyl-, methyl ester, C₁₄H₂₈O₂; Phosphonic acid, 1,2-ethanediybis-, tetraethyl ester, C₁₀H₂₄O₆P₂; Ala-Thr, C₇H₁₄N₂O₄; 6,10-Dimethyl-3-(1-methylethylidene)-1-cyclodecene, C₁₅H₂₆; 2,6-Diaminopimelic acid, C₇H₁₄N₂O₄; Monomyristin, C₁₇H₃₄O₄; cis-6-Octadecenoic acid, C₁₈H₃₄O₂; Phytol, C₂₀H₄₀O; 2,4,4-Trimethyl-3-hydroxymethyl-5a-(3-methyl-but-2-enyl)-cyclohexene, C₁₅H₂₆O; 1,3,3-Trimethyl-2-hydroxymethyl-3,3-dimethyl-4-(3-methylbut-2-enyl)-cyclohexene, C₁₅H₂₆O; Methyl 5,9,23-nonacosatrienoate, C₃₀H₅₄O₂; Cholestan-3-one, cyclic 1,2-ethanediy acetal, (5 α)-, C₂₉H₅₀O₂; Oxirane, tetradecyl-, C₁₆H₃₂O; Bicyclo[2.2.1]heptane, 1,7,7-trimethyl-, C₁₀H₁₈; Photocitral A, C₁₀H₁₆O; 1-Methyl-4-isopropyl-cyclohexyl 2-hydroperfluorobutanoate, C₁₄H₂₀F₆O₂; Photocitral B, C₁₀H₁₆O; Glycerol 1-stearate, C₂₁H₄₂O₄; Oleoyl-L- α -lysophosphatidic acid, C₂₁H₄₁O₇P; 1-Naphthalenepropanol, α -ethenyldecahydro-2,4-dihydroxy- α ,2,5,5,8a-pentamethyl-, [1R-(1 α (R*),2 β ,4 α ,4 α ,8 α)]-, C₂₀H₃₆O₃; 2(1H)-Naphthalenone, octahydro-4a-methyl-7-(1-methylethyl)-, (4 α ,7 β ,8 α)-, C₁₄H₂₄O; Naphtho[1,2-b]furan-2,8(3H,4H)-dione, octahydro-3,5a,9-trimethyl-, [3S-(3 α ,3 α ,5 α ,9 β ,9 α ,9 β)]-, C₁₅H₂₂O₃; 8-Dodecen-1-ol, acetate, (Z)-, C₁₄H₂₆O₂; Elaidic acid, C₁₈H₃₄O₂; Heptadecanoic acid, ethyl ester, C₁₉H₃₈O₂; Undecanoic acid, 2,8-dimethyl-, methyl ester, C₁₄H₂₈O₂; Octadecanoic acid C₁₈H₃₆O₂; 1,5,9-Triazacycloheptacosan-10-one, C₁₈H₃₇N₃O; Octadecanoic acid, 2-oxo-, methyl ester, C₁₉H₃₆O₃; 9-Octadecenoic acid (Z)-, phenylmethyl ester, C₂₅H₄₀O₂; 6H-Benzofuro[3,2-c][1]benzopyran, 3,9-dimethoxy-, C₁₇H₁₄O₄; Silicic acid, diethyl bis(trimethylsilyl) ester, C₁₀H₂₈O₄Si₃; 4,4'-Isopropylidene-bis(2-chlorophenol), C₁₅H₁₄Cl₂O₂; 3H-1,4-Benzodiazepin-2-amine, 7-

chloro-N-methyl-5-phenyl-, C₁₆H₁₄ClN₃; Quinoxaline, 2,3-diphenyl-, C₂₀H₁₄N₂; Flurazepam, C₂₁H₂₃ClFN₃O; 1-Cyano-4-diphenyl(tert-butyl)silyloxybenzene, C₂₃H₂₃NOSi; 10H-Phenothiaphosphine, 7-chloro-2-fluoro-10-hydroxy-, 10-oxide, C₁₂H₇ClFO₂PS; 9-Acridanone, 4-hydroxy-1,2,3-trimethoxy-10-methyl-, C₁₇H₁₇NO₅; Gln-Gln-Arg, C₁₆H₃₀N₈O₆; 2(1H)-Pyrimidinone, 5-chloro-4,6-diphenyl-, C₁₆H₁₁ClN₂O; Hexestrol, di-TMS, C₂₄H₃₈O₂Si₂; 3-Isopropoxy-1,1,1,5,5,5-hexamethyl-3-(trimethylsiloxy)trisiloxane, C₁₂H₃₄O₄Si₄; Cyclotetrasiloxane, octamethyl-, C₈H₂₄O₄Si₄; 1,3,3-Trimethyl-1-(4'-methoxyphenyl)-6-methoxyindane, C₂₀H₂₄O₂; and 1,3,5,7-Tetraethyl-1-butoxycyclotetrasiloxane, C₁₂H₃₂O₅Si₄.

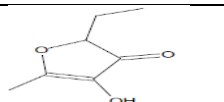
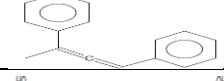
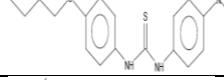
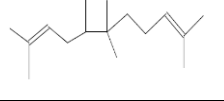
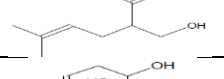
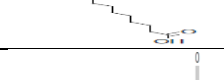
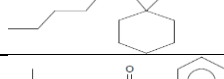
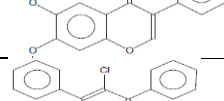
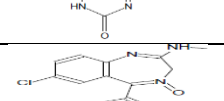
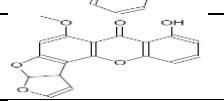
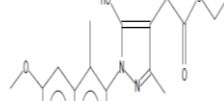
From the results obtained as shown in Table 4, the dye extract contains 30.86% of pentanoic acid, 4- methyl-, ethyl ester; 14.98% of heptanoic acid, ethyl ester; 12.27% of 2-ethyl-4-hydroxy-5-methyl-3(2H)-furanone; 5.58% of chlordiazepoxide; 4.06% of D-arabinose; 3.2% of 2(1H)-pyrimidinone, 5-chloro-4,6-diphenyl-; 2.9% of 1,3,5,7-tetraethylbicyclo[3.3.1]tetrasiloxane; 2.46% of 1-(3-Hydroxy-4-methylphenyl)-1,3,3,6-tetramethylindan-5-ol; 2.44% of isocitric acid lactone; 2.28% of sterigmatocystin; 2.19% of β -estradiol; 2.12% of o-cymene; 2.07% of hexadecanoic acid, ethyl ester; 1.77% of ethyl [5-hydroxy-1-(6-methoxy-4-methyl-3-quinolinyl)-3-methyl-1H-pyrazol-4-yl]acetate; 1.53% of 2,4,7,9-tetramethyl-5-decyne-4,7-diol; 1.52% of ethyl 14-methyl-hexadecanoate and others are minor quantity.

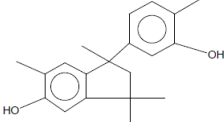
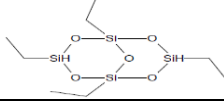
The presence of many biochemical compounds with their conjugate single and double bonds in the dye extract of almond leaves give strong contribution to the color, biological and medicinal properties of the dye together with its application in textile industry to produce medicinal textile that is potent to heal and prevent diseases. From the literatures, the identified compounds such as esters, naphthalene possess vital biological and medical potency for textile finishing treatment against bacterial, softness, pathogens, fungi, microbial activity, tumor (Awuchi, 2019; Gomathi, Kalaiselvi, Ravikumar, Devaki, and Uma, 2015) and ultraviolet radiation among others (Mongkholarattanasit, Kryštůfek, Wiener and Viková, 2011, Mongkholarattanasit, Cholachatpinyo, Tubtimthai, and Rungruangkitkrai, 2014). Ester compounds have the property of antioxidant and antimicrobial activities. They are also essential organic compounds with immense number of commercial applications. These compounds are mainly utilized in cosmetics, detergents, fragrances, flavors and pharmaceuticals (Foresti, Errazu, Ferreira, 2005; Gomathi et al, 2015).

Table 4: Results for GC/Ms Analysis

S/ N	Compound	RT	Area Sum %	Molecular Formulae	Chemical Structure	Molecular Mass	Library	Group
1	D-Arabinose	2.7	4.06	C ₅ H ₁₀ O ₅		150	Nist	sugar
2	Pentanoic acid, 4-methyl-, ethyl ester	2.9	30.86	C ₈ H ₁₆ O ₂		144	Mainlib	Ester
3	o-Cymene	4.4	2.12	C ₁₀ H ₁₄		134	Mainlib	Aromatic
4	Heptanoic acid, ethyl ester	4.7	14.98	C ₉ H ₁₈ O ₂		158	Replib	Ester
5	9-cis-Retinal	5.3	0.59	C ₂₀ H ₂₈ O		284	Nist	Carotene
6	cis-2-Methyl- β -methyl- β -nitrostyrene	5.5	0.87	C ₁₀ H ₁₁ NO ₂		177	Mainlib	Nitro
7	Isocitric acid lactone	5.8	2.44	C ₆ H ₆ O ₆		174	Nist	Ketone Acid
8	β -Estradiol	5.9	2.19	C ₁₈ H ₂₄ O ₂		272	Nist	Steroid Alcohol
9	β -Estradiol 3,17-dipropionate	6.2	0.73	C ₂₄ H ₃₂ O ₄		384	Nist	Steroid Ester
10	Guanine	6.9	0.58	C ₅ H ₅ N ₅ O		151	Nist	Alkaloid

Characterization of Natural Dye Extract obtained from Almond Leaves

11	2-Ethyl-4-hydroxy-5-methyl-3(2H)-furanone	7	12.27	C7H10O3		142	Nist	Ketone
12	Hexadecanoic acid, ethyl ester	9.3	2.07	C18H36O2		284	Replib	Ester
13	1,3-Diphenylbuta-1,2-diene	10.2	0.37	C16H14		206	Mainlib	Hydrocarbon
14	Undecanedioic acid	11.4	0.43	C11H20O4		216	Nist	Acid
15	Thiambutosine	11.6	0.32	C19H25N3OS		343	Replib	Ether Amide
16	2,4,7,9-Tetramethyl-5-decyne-4,7-diol	11.9	1.53	C14H26O2		226	Nist	Alcohol
17	2-Methyl-3-(3-methyl-but-2-enyl)-2-(4-methyl-pent-3-enyl)-oxetane	12.2	0.31	C15H26O		222	Mainlib	Hydrocarbon
18	(±)-Lavandulol	12.4	0.69	C10H18O		154	Nist	Alcohol
19	(1S,2E,4S,5R,7E,11E)-Cembra-2,7,11-trien-4,5-diol	12.6	0.48	C20H34O2		306	Mainlib	Alcohol
20	Dodecanedioic acid	13.3	0.69	C12H22O4		230	Nist	Acid
21	Ethyl 14-methyl-hexadecanoate	13.5	1.52	C19H38O2		298	Replib	Ester
22	3-Hydroxydodecanoic acid	13.9	0.71	C12H24O3		216	Nist	Acid
26	1-Hexyl-1-nitrocyclohexane	16.8	0.64	C12H23NO2		213	Mainlib	Hydrocarbon
26b	4H-1-Benzopyran-4-one, 6,7-dimethoxy-3-phenyl-	15.3	0.36	C17H14O4		282	Mainlib	Flavonoid
27	2(1H)-Pyrimidinone, 5-chloro-4,6-diphenyl-	19.3	3.2	C16H11ClN2O		282	Mainlib	Alkaloid Ketone
28	Chlordiazepoxide	22.3	5.58	C16H14ClN3O		299	Nist	Alkaloid
29	Sterigmatocystin	22.6	2.28	C18H12O6		324	Nist	Flavonoid
30	Ethyl [5-hydroxy-1-(6-methoxy-4-methyl-3-quinoliny)-3-methyl-1H-pyrazol-4-yl]acetate	23.1	1.77	C19H21N3O4		355	Mainlib	Alkaloid Ester

31	1-(3-Hydroxy-4-methylphenyl)-1,3,3,6-tetramethylindan-5-ol	24.	2.46	C ₂₀ H ₂₄ O ₂		296	Mainli b	Alcohol
32	1,3,5,7-Tetraethylbicyclo[3.3.1]tetrasiloxane	24. 3	2.9	C ₈ H ₂₂ O ₅ Si ₄		310	Mainli b	Silicon

IV. Conclusion

Almond leaves are a vital source of natural dye containing many bioactive compounds which are useful for textile finishing. Their natural dye is useful by imparting multifunctional properties such as antimicrobial activity, anti-fungi, anticancer, anti-allergic, antioxidant, anti-inflammation, ultraviolet radiation among others on textiles. Among the bioactive compounds identified are flavonoids, ester, acid, alcohol, nitro, alkaloids, steroids, ketones, phenols, aromatic, terpenes with trace of heavy metals such as chromium, cadmium, iron, zinc, copper, mercury, nickel and lead. Some of the heavy metals such as iron, chromium and zinc perhaps assist in fixing the dye on fiber. The natural dye of almond leaves can be utilized in textile finishing by replacing the synthetic dyes counterpart. Textile dyed with natural dye obtained from almond leaves can play a very huge role in medicine in the prevention and cure of ailments as the flavonoids found in the dye extract have medicinal efficacy as antibacterial, anticancer, antioxidant, anti-inflammation, anti-fungi and antiviral.

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