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Synthesis and Characterization of Some Metal Complexes Using Herbal Flavonoids

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Abstract

The article describes the synthesis and characterization of Ni-flavonoid complex, Cu-flavonoid complex and Zn-flavonoid complex. The complexes and the flavonoid extracts were characterized using FTIR and UV-Visible spectrophotometer. The results for FTIR spectra clearly showed the formation of complexes as the bands assigning to the carbonyl group C=O shifted to the lower wave number when compared with that of the free ligands. The complexes and the flavonoids extracts when analyzed using UV-Visible spectrophotometer, most of the spectra of the complexes were absorbed at the range of 200 nm to 400 nm and all the spectra of the flavonoids extracts were also absorbed between 200 nm to 400 nm. These results revealed that complexes were formed at slightly acidic condition between the pH values 3.51 to 4.65. In general the results revealed that the conductivity values of Ni-flavonoid complexes <Cu-flavonoid complexes <Zn-flavonoid complexes. The lowest conductivity of all the complexes was obtained from Zn-flavonoid complexes as a result of its largest surface area, weak bonding and being far away from the nucleus. Therefore, Ni-flavonoid complexes had higher conductivity because of their small surface area and are closer to the nucleus and having stronger bonding than Cu-flavonoid complexes and Zn-flavonoid complexes. The highest melting point of all the complexes was obtained from Zn-flavonoid complex of *Ocimum gratissimum* while the lowest melting point was obtained from Ni-flavonoid complex of *Moringa oleifera*. Ni-flavonoid complex of *Moringa olifera* had shorter time to be melted than all the complexes and weak bonding exist in the complex but Zn-flavonoid complex of *Ocimum gratissimum* had strong bonding and take longer time to be melted.

Keywords: Synthesis; Characterization; Flavonoid or bioflavonoid; Complex; Herbal; Chelate

Introduction

Flavonoids or bioflavonoids from the Latin word flavus meaning yellow, their color in nature are a class of plant secondary metabolites. Flavonoids were referred to as Vitamin P [1]. Probably because of the effect they had on the permeability of vascular capillaries, but the term has since fallen out of use [2]. Flavonoids are widely distributed in plants, fulfilling many functions. Flavonoids are the most important plant pigments for flower coloration, producing yellow or red/blue pigmentation in petals designed to attract pollinator animals [3].

The unique nutrient richness of every whole, natural food can be showcased in a variety of ways. But there is no better way to highlight the unique nutrient richness of foods than to focus on their flavonoid content! Flavonoids are a quite remarkable group of phytonutrients that fall into the chemical category of polyphenols. They're perhaps most famous for their rich diversity of color-providing pigments. The name of these phytonutrients actually derives from their color-related chemistry. As a group, however, flavonoids are highly bioactive and play a wide variety of different roles in the health of plants, animals, and human health.

The flavonoid nutrient family is one of the largest nutrient families known to scientists. Over 6,000 unique flavonoids have been identified in research studies, and many of these flavonoids are found in plants that are routinely enjoyed in delicious cuisines throughout the world. In terms of nutrient richness, we get far more flavonoids from plant foods than from animal foods, and in particular, vegetables and fruits can be especially nutrient-rich in this type of phytonutrient.

Flavonoids are best known for their antioxidant and anti-inflammatory health benefits as well as the support of the cardiovascular and nervous systems. Because they also help support detoxification of potentially tissue-damaging molecules, their intake has often, although not always, been associated with decreased risk of certain types of cancers, including lung and breast cancer [4].

Flavonoids are widely distributed in plants, fulfilling many functions. Flavonoids are the most important plant pigments for flower coloration, producing yellow or red/blue pigmentation in petals designed to attract pollinator animals. In higher plants, flavonoids are involved in UV filtration, symbiotic nitrogen fixation and floral pigmentation.

They may also act as chemical messengers, physiological regulators, and cell cycle inhibitors. Flavonoids secreted by the root of their host plant help Rhizobia in the infection stage of their symbiotic relationship with legumes like peas and beans. In addition, some

flavonoids have inhibitory activity against organisms that cause plant diseases [3].

Flavonoids (specifically flavanoids such as the catechins) are "the most common group of polyphenolic compounds in the human diet and are found ubiquitously in plants". The widespread distribution of flavonoids, their variety and their relatively low toxicity compared to other active plant compounds (for instance alkaloids) mean that many animals, including humans, ingest significant quantities in their diet. Foods with a high flavonoid content include fruits and vegetable. E.g., parsley, onions, blueberries and other berries, black tea, green tea and bananas, all citrus fruits, red wine and dark chocolate (with a cocoa content of 70% or greater) [5].

A variety of potential health benefits including reduced risk for coronary artery disease and cancer are thought to be associated with dietary flavonoids [6]. These effects of flavonoids are generally attributed to their ability to scavenge reactive oxygen and nitrogen species (O2– • OH, NO•, RO•, ROO•) and reduce oxidative stress, which may contribute to the progression of many diseases. For these reasons flavonoid-rich diet, supplements and cosmetics are widely recommended for improving health status and prevention of chronic diseases [7].

Experimental

Equipments/apparatus

Fourier Transform Infrared (FT-IR), UV/Visible Spectrometer, laboratory glass ware, analytical balance, Pestle and Mortar, Sieve, Whatman filter paper.

Collection and preparation of plant materials

Fresh parts of five herbal plants leaves *Vernonia baldwinii, Moringa oleifera, Telfairia occidentalis, Ocimum gratissimum* and *Cassia tora* were collected from different areas in Jalingo and Ardo-kola Local Government Area of Taraba State in the North Eastern region of Nigeria. The plant materials were authenticated at the Department of Chemistry Modibbo Adama University of Technology Yola Adamawa State.

The fresh plant materials were collected, and the voucher specimen were numbered 1-5 and kept in Chemistry Researsh Laboratory of Modibbo Adama University of Technology Yola Adamawa State. The part of the plant materials collected were freed from twigs and extraneous matter. Soil grit, Sand and dirty were removed by sifting. In other to remove the remnants of adhering foreign matter, the samples were rapidly and thoroughly washed under tap water and rinsed with distilled water and then shade dried at room temperature for 15 days. After drying, the plant materials were ground to fine powder and transferred into airtight containers with proper lebeling for future use.

Flavonoid extraction

About 5 g of the dried sample was extracted with ethanol 70% for 60 min. at 60°C. Extracts were filtered in vacuum using whatman filter paper. Aqueous as well as hydrochloric extracts were evaporated to dryness. The dried weigh was measured. The yield was defined:

Crude extract/Plant material weight × 100

Synthesis of metal-flavonoid complexes

A solution of Copper chloride, Zinc sulphate, Nickel chloride each (0.0249 g, 1.25×10^{-4} mol) was measured and (2 cm^3) distilled water was added and the solution was slowly added drop wise to a solution of flavonoid (0.146 g, 2.5×10^{-4} mol) in methanol (10 cm^3). The mixture was stirred for 30 min at room temperature. The complex was filtered in a vacuum system, washed with water and dried by lyophilization. A pure green solid was obtained and weighed.

Results and Discussion

Flavonoid extracts

The result for the extraction of flavonoid in *Moringa oleifera, Cassia tora, Ocimum gratissimum, Vernonia* and *Telfairia occidentalis* leaves is presented in Table 1. The result shows that Vernonia leaves produced highest percentage yield of flavonoid extracts while *Moringa oleifera* leaves produced the lowest percentage yield of the flavonoid extracts. The flavonoid produced in *Moringa oleifera* leaves is <*Cassia tora* leaves>*Ocimum gratissimum* leaves<*Vernonia* leaves>*Telfairia occidentalis*.

Sample	gram (g)[a]	% yield[b]
Moringa oleifera	0.9431	18.86
Cassia tora	1.3527	27.05
Ocimum gratissimum	1.1392	22.78
Verninia	1.8025	36.05
Telfairia occidentalis	1.3083	26.17
[a]Expressed as g of dry sample, [b]Expressed as % yield of dry sample		

Table 1: Flavonoids extracts in gram and percentage yield in the plant leaves.

The synthesized metal-flavonoid complexes

The percentage yield for the complexes in Table 2 shows that Zn-flavonoid complex in *Ocimum gratissimum* has the highest percentage yield while Zn-flavonoid complex in *Moringa oleifera* contained the lowest percentage yield. The percentage yield of the metal-flavonoid complexes were higher when compared with the result of Regina [8].

Sample	gram (g)[a]	% yield[b]
Metal-flavonoid complexes of *Moringa oleifera* extracts		

Cu-flavonoid complex	0.1052	72.06
Zn-flavonoid complex	0.0998	68.36
Ni-flavonoid complex	0.1154	79.04
Metal-flavonoid complexes of *Cassia tora* extracts		
Cu-flavonoid complex	0.1228	84.11
Zn-flavonoid complex	0.1225	85.90
Ni-flavonoid complex	0.1399	95.82
Metal-flavonoid complexes of *Ocimum gratissimum* extracts		
Cu-flavonoid complex	0.1243	85.51
Zn-flavonoid complex	0.1564	107.12
Ni-flavonoid complex	0.1132	77.53
Metal-flavonoid complexes of *Vernonia* extracts		
Cu-flavonoid complex	0.0950	65.07
Zn-flavonoid complex	0.1077	73.77
Ni-flavonoid complex	0.1135	77.74
Metal-flavonoid complexes of *Telfairia occidentalis* extracts		
Cu-flavonoid complex	0.1483	101.58
Zn-flavonoid complex	0.1287	88.15
Ni-flavonoid complex	0.1286	88.08
[a]Expressed as g of dry sample, [b]Expressed as % yield of dry sample.		

Table 2: Percentage yield of metal-flavonoid complexes from flavonoid extracts of *Moringa oleifera, Cassia tora, Ocimum gratissimum, Vernonia baldwinii* and *Telfairia occidentalis* leaves.

The physical properties of the complexes

In this study, the investigation of physical properties of complexes in Table 3 indicates that the highest pH value of the complexes was found in Zn-flavonoid complex of *Vernonia baldwinii* while the lowest pH value was found in Zn-flavonoid complex of *Cassia tora*. According to these results, the complexes were formed at slightly acidic condition between the pH value 3.51 to 4.65. The optimal pH for complex formation, although strongly dependent on the features of the metal ion, is around pH 6. Complex formation at pH values lower than 3.0 is difficult because the flavonoids are predominantly present in their undissociated form. Although higher pH values favour deprotonation of flavonoids and consequently, more complex species at higher pH values metal ions are often involved in side reaction (hydrolysis) and hydroxo-complexes are formed [9-12]. In general the conductivity values of Ni-flavonoid complexes <Cu-flavonoid complexes <Zn-flavonoid complexes. The lowest conductivity of all the complexes was obtained from Zn-flavonoid complexes as a result of its largest surface area, weak bonding and being far away from the nucleus. Therefore, Ni-flavonoid complexes had higher conductivity because of their small surface area and are closer to the nucleus and having stronger bonding than Cu-flavonoid complexes and Zn-flavonoid complexes. The highest melting point of all the complexes was obtained from Zn-flavonoid complex of *Ocimum gratissimum* while the lowest melting point was obtained from Ni-flavonoid complex of *Moringa oleifera*. The results shows that Ni-flavonoid complex of *Moringa olifera* had shorter time to be melted than all the complexes and weak bonding exist in the complex but Zn-flavonoid complex of *Ocimum gratissimum* had strong bonding and take longer time to be melted. The melting point of the complexes were low when compared with the result of Regina [13] as a result of different in samples and environmental condition. The pH values of the complexes agreed with the pH value stated by Dušan and Vesna [14] for metal-flavonoid complexes.

Sample	pH	Conductivity (μS)a	Melting point (°C)b
Metal-flavonoid complexes of *Moringa oleifera* extracts			

Cu-flavonoid complex	3.61	60.23	116
Zn-flavonoid complex	3.71	62.40	128
Ni-flavonoid complex	3.55	58.17	80
Metal-flavonoid complexes of *Cassia tora* extracts			
Cu-flavonoid complex	3.62	69.17	116
Zn-flavonoid complex	3.26	27.10	124
Ni-flavonoid complex	4.15	57.00	118
Metal-flavonoid complexes of *Ocimum gratissimum* extracts			
Cu-flavonoid complex	3.78	59.67	130
Zn-flavonoid complex	3.91	66.73	138
Ni-flavonoid complex	4.01	62.60	120
Metal-flavonoid complexes of *Vernonia* extracts			
Cu-flavonoid complex	3.76	26.40	101
Zn-flavonoid complex	4.65	66.20	120
Ni-flavonoid complex	3.78	47.33	128
Metal-flavonoid complexes of *Telfairia occidentalis* extracts			
Cu-flavonoid complex	3.97	67.28	112
Zn-flavonoid complex	3.96	82.73	124
Ni-flavonoid complex	4.09	62.00	126
[a]Expressed as µS of the sample, [b]Expressed as °C of the sample.			

Table 3: Some investicated physical properties for metal-flavonoid complexes of *Moringa oleifera, Cassia tora, Ocimum gratissimum, Vernonoia* and *Telfairia occidentalis* plant leaves extracts.

The FTIR results

The pH, Conductivity and Melting point obtained from metal-flavonoid complexes of *Moringa oleifera, Cassia tora, Ocimum gratissimum, Vernonoia* and *Telfairia occidentalis* plant leaves extract as shown in Tables 4-8 and graphical represention shown in Figures 1a-10.

Cu-flavonoid complex	Zn-flavonoid complex	Ni-flavonoid complex	Flavonoid extracts	Assignment
13983	-	-	-	-O-H stretch alcohols and phenols
3891	-	-	-	-O-H stretch alcohols and phenols
-	3857	-	-	-O-H alcohols, phenols from carbohydrates
-	3738	3785	3706	-O-H stretch alcohols and phenols
3403	3400	-	-	-O-H stretch alcohols and phenols
2938	2938	2960	2920	-C-H stretch alkanes
2358	-	2373	-	-C≡N stretch nitrites
1723	1725	1725	1732	-C=O stretch aldehydes, saturated aliphatics
-	1641	1650	-	-C=C stretch alkenes
1639	-	-	1614	-N-H bend 1° amines

1511	1505	1523	1513	-N-O asymmetric stretch nitro compounds
1411	1422	1400	1418	-C-C stretch (in ring) aromatics
-	-	1142	1214	-C-H wag (-CH2X) alkyl halides
1052	1074	1050	1023	-C-O stretch alcohols, carboxylic acids, esters, ethers
-	-	-	827	-C-Cl stretch alkyl halides
600	608	-	608	-C-Br stretch alkyl halides
514	498	-	-	-C-Br stretch alkyl halides
389	418	415	-	-C-Br stretch alkyl halides

Table 4: Assignment of FTIR Absorption for Cu-flavonoid complex, Zn-flavonoid complex, Ni-flavonoid complex and flavonoid extracts from *Moringa oleifera* dried plant leaves.

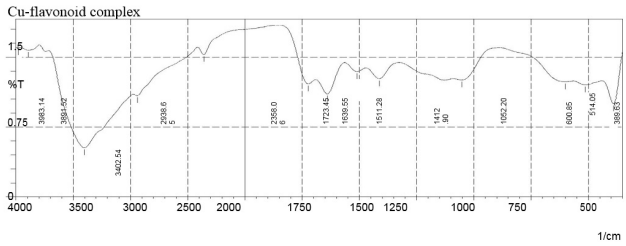

Figure 1a: FTIR Absorption Spectra for Cu-flavonoid complex from *Moringa oleifera* leaves.

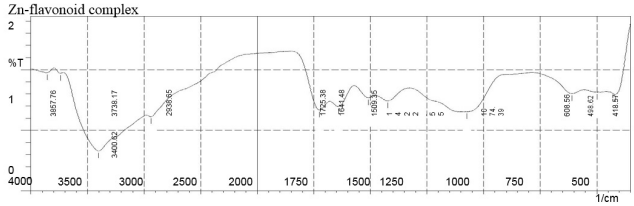

Figure 1b: FTIR Absorption Spectra for Zn-flavonoid complex from *Moringa oleifera* leaves.

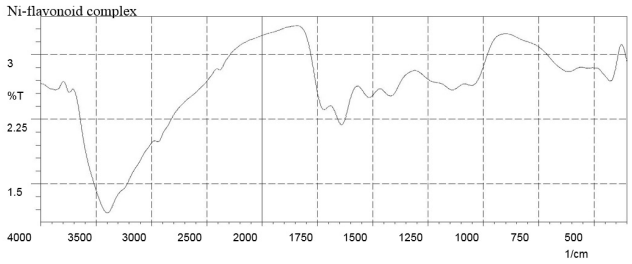

Figure 1c: FTIR Absorption Spectra for Ni-flavonoid complex from *Moringa oleifera* leaves.

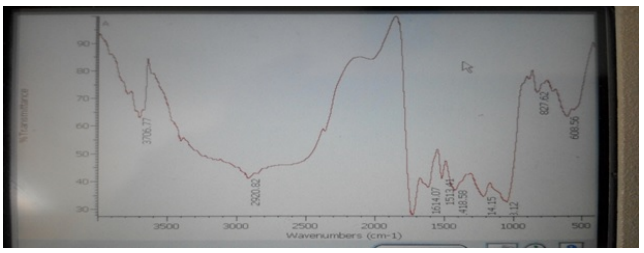

Figure 2: FTIR Absorption Spectra for flavonoid extracts from *Moringa oleifera* leaves.

Cu-flavonoid complex	Zn-flavonoid complex	Ni-flavonoid complex	Flavonoid extracts	Assignment
3993	-	3987	-	-O-H stretch alcohols and phenols
-	-	3922	-	-O-H stretch alcohols and phenols
-	3861	-	-	-O-H stretch alcohols, phenols and carboxylic acids from carbohydrates
3857	-	-	-	-O-H stretch alcohols and phenols from carbohydrates
3737	3737	-	-	-O-H stretch alcohols and phenols

3403	-	-	-	-O-H stretch, H-bonded, alcohols and phenols
-	3397	3394	-	-O-H stretch, H-bonded, alcohols and phenols
2946	2933	-	-	-C-H stretch alkanes
2380	-	-	2361	-C≡N stretch nitriles
-	1723	1724	1727	-C=O stretch aldehydes, saturated aliphatics
1641	-	-	-	-C=C stretch alkenes
-	1636	1636	1622	-N-H bend 1o amines
1510	1530	-	1511	-N-O asymmetric stretch nitro compounds
-	1482	-	-	-N-O asymmetric stretch nitro compounds
1414	1431	1413	1419	-N-O asymmetric stretch nitro compounds
1132	1196	1125	1210	-C-O stretch alcohols, carboxylic acids, esters, ethers
-	1117	-	-	-C-N stretch aliphatic amines
1050	1055	-	-	-C-N stretch aliphatic amines
-	-	-	891	-C-H "OOP" aromatics
583	-	-	-	-C-Br stretch alkyl halides
486	422	485	-	-C-Br stretch alkyl halides
-	-	400	-	-C-Br stretch alkyl halides
396	-	-	-	-C-Br stretch alkyl halides

Table 5: Assignment of FTIR Absorption for Cu-flavonoid complex, Zn-flavonoid complex, Ni-flavonoid complex and flavonoid extracts from *Cassia tora* dried plant leaves extracts.

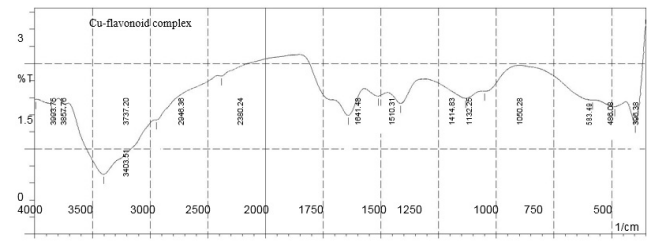

Figure 3a: FTIR Absorption Spectra for Cu-flavonoid complex from *Cassia tora* leaves.

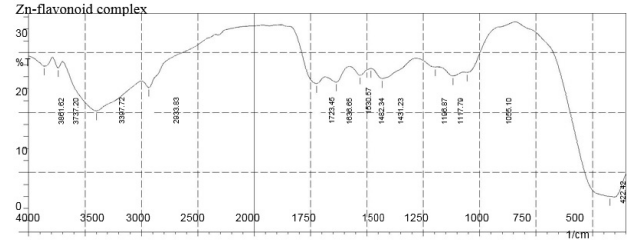

Figure 3b: FTIR Absorption Spectra for Zn-flavonoid complex from *Cassia tora* leaves.

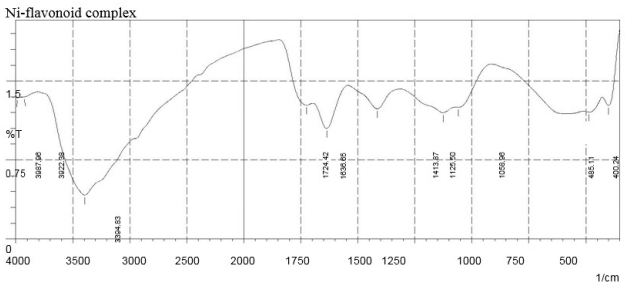

Figure 3c: FTIR Absorption Spectra for Ni-flavonoid complex from *Cassia tora* leaves.

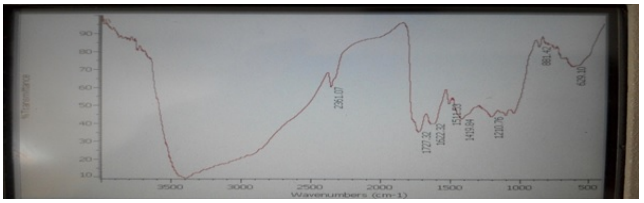

Figure 4: FTIR Absorption Spectra for flavonoid extracts from *Cassia tora* leaves.

Cu-flavonoid complex	Zn-flavonoid complex	Ni-flavonoid complex	Flavonoid extracts	Assignment
-	-	3972	-	-O-H stretch alcohols and phenols
-	3860	3868	-	-O-H alcohols and phenols from carbohydrates
-	3741	-	-	-O-H stretch alcohols and phenols
-	3634	-	3671	-O-H stretch free hydroxyl, alcohols and phenols
3354	-	3399	-	-O-H stretch alcohols and phenols
2922	-	-	-	-C-H stretch alkanes
-	2351	2353	2362	-C≡N stretch nitriles
2027	-	-	-	-C≡C stretch alkynes
1685	1688	-	1733	-C=O stretch alpha, beta-unsaturated esters
-	-	1640	-	-C=C stretch alkenes
1636	-	-	-	-N-H bend 1o amines
1633	-	-	-	-N-H bend 1o amines
1505	1531	1518	-	-N-O asymmetric stretch nitro compounds
1457	-	-	-	-C-H bend alkanes
1420	-	1416	1448	-C-H bend scissoring mode in alkanes
1371	-	-	-	-C-H bend alkanes
1322	-	-	-	-C-H rock alkanes
1237	-	-	1216	-C-H wag (-CH_2X) alkyl halides
1166	-	1138	-	-C-O stretch alcohols, carboxylic acids, esters, ethers
1021	-	-	1039	-C-N stretch aliphatic amines
894	-	-	-	-C-H “OOP” aromatics
834	-	-	-	-C-Cl stretch alkyl halides
-	666	632	665	-C (triple bond) C-H: C-H bend alkynes

-	426	443	-	-C-Br stretch alkyl halide

Table 6: Assignment of FTIR Absorption for Cu-flavonoid complex, Zn-flavonoid complex, Ni-flavonoid complex and flavonoid extracts from *Ocimum gratissimum* dried plant leaves.

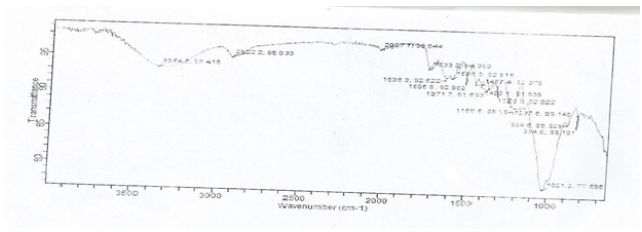

Figure 5a: FTIR Absorption Spectra for Cu-flavonoid complex from *Ocimum gratissimum* leaves.

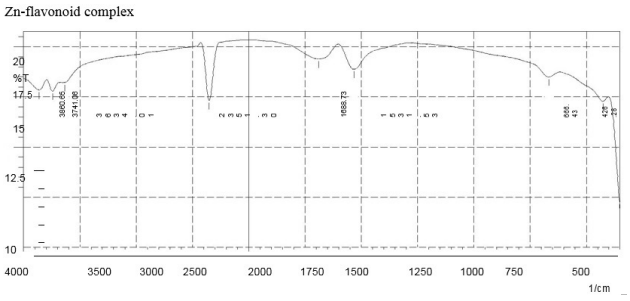

Figure 5b: FTIR Absorption Spectra for Zn-flavonoid complex from *Ocimum gratissimum* leaves.

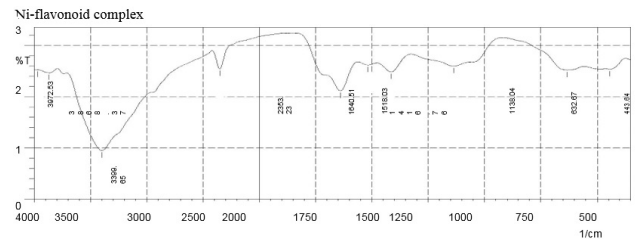

Figure 5c: FTIR Absorption Spectra for Zn-flavonoid complex from *Ocimum gratissimum* leaves.

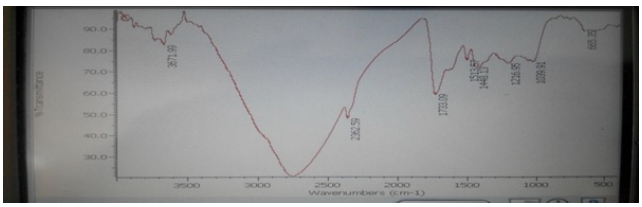

Figure 6: FTIR Absorption Spectra for flavonoid extracts from *Ocimum gratissimum* leaves.

Cu-flavonoid complex	Zn-flavonoid complex	Ni-flavonoid complex	Flavonoid extracts	Assignment
3966	3933	3923	-	-O-H stretch alcohols and phenols
3868	3879	3875	-	-O-H alcohol and phenols from carbohydrates
-	-	-	3809	-O-H stretch, H-bonded, alcohols and phenols
-	-	-	3761	-O-H stretch, H-bonded, alcohols and phenols
-	-	-	3667	-O-H stretch, H-bonded, alcohols and phenols
-	3406	3402	-	-O-H stretch, H-bonded, alcohols and phenols
3398	-	-	-	-O-H stretch, H-bonded, alcohols and phenols
2938	2935	2938	2924	-C-H stretch alkanes
2353	2356	-	2359	-C≡N stretch nitriles
-	1712	1710	1717	-C=O stretch aldehydes, saturated aliphatic

1640	1640	1640	-	-C=C stretch alkenes
-	-	1510	1519	-N-O asymmetric stretch nitro compound
1411	1412	1416	1448	-C-C stretch (in ring) aromatic
1141	1131	1136	1223	-C-O stretch alcohols, carboxylic acids, esters, ethers
1049	-	1035	-	-C-N stretch aliphatic amines
612	628	616	-	-C (triple bond) C-H: C-H bend alkynes
-	538	-	-	-C-Br stretch alkyl halides
397	-	393	-	-C-Br stretch alkyl halides

Table 7: Assignment of FTIR Absorption for Cu-flavonoid complex, Zn-flavonoid complex, Ni-flavonoid complex and flavonoid extracts from *Vernonia baldwinii* dried plant leaves.

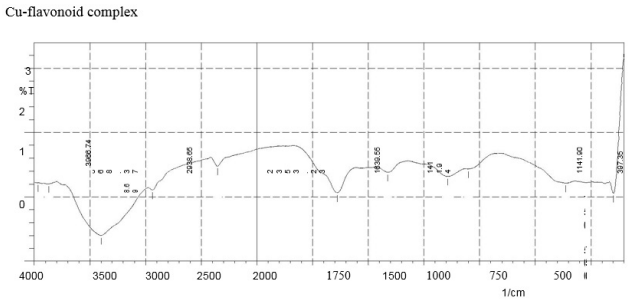

Figure 7a: FTIR Absorption Spectra for Cu-flavonoid complex from *Vernonia baldwinii* leaves.

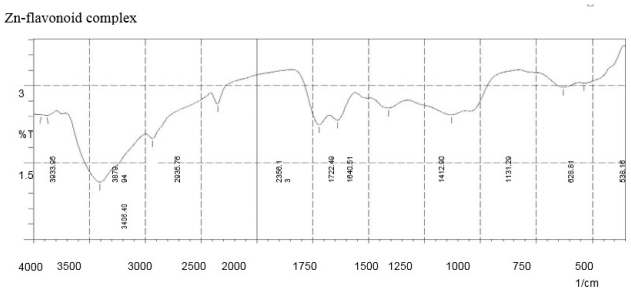

Figure 7b: FTIR Absorption Spectra for Zn-flavonoid complex from *Vernonia baldwinii* leaves.

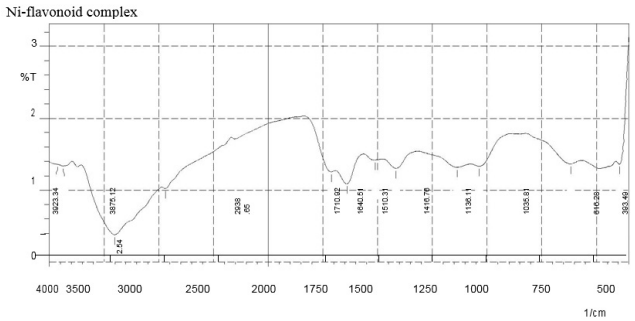

Figure 7c: FTIR Absorption Spectra for Ni-flavonoid complex from *Vernonia baldwinii* leaves.

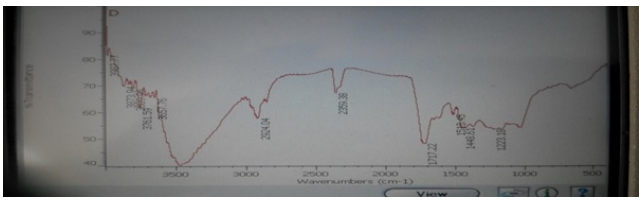

Figure 8: FTIR Absorption Spectra for flavonoid extracts from *Vernonia baldwinii* leaves.

Cu-flavonoid complex	Zn-flavonoid complex	Ni-flavonoid complex	Flavonoid extracts	Assignment
-	3992	-	-	-O-H stretch alcohols and phenols
3862	-	3871	-	-O-H stretch alcohols, phenols and carboxylic acids from carbohydrates
-	3858	3865	3861	-O-H alcohols and phenols from carbohydrates

-	-	-	3565	-O-H stretch, free hydroxyl alcohols, phenols
3743	-	-	-	-O-H stretch alcohols and phenols
3341	3402	-	-	-O-H stretch, H-bonded, alcohols and phenols
-	-	3389	-	-O-H stretch, H-bonded, alcohols and phenols
2941	2934	2952	-	-C-H stretch alkanes
2298	2382	-	2357	-C≡N stretch nitrites
-	1718	1716	1723	-C=O stretch alpha, beta-unsaturated esters
1645	1649	1644	-	-C=C stretch alkenes
1525	1512	-	-	-N-O asymmetric stretch nitro compound
1413	1419	1413	1457	-C-C stretch (in ring) aromatic
-	1126	-	1100	-C-O stretch alcohols, carboxylic acids, esters, ethers
1048	-	1054	-	-C-N stretch aliphatic amines
-	599	604	-	-C-Br stretch alkyl halides
445	418	405	-	-C-Br stretch alkyl halides
399	-	-	-	-C-Br stretch alkyl halides

Table 8: Assignment of FTIR Absorption for Cu-flavonoid complex, Zn-flavonoid complex, Ni-flavonoid complex and flavonoid extracts from *Telfairia occidentalis* dried plant leaves.

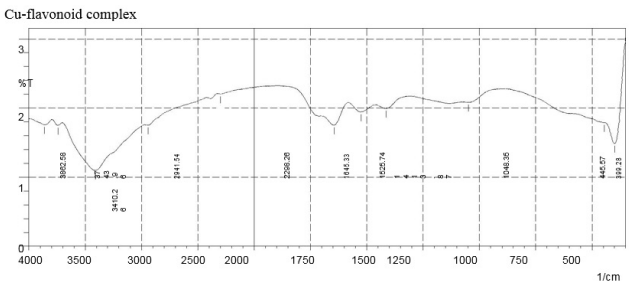

Figure 9a: FTIR Absorption Spectra for Cu-flavonoid complex from *Telfairia occidentalis* leaves.

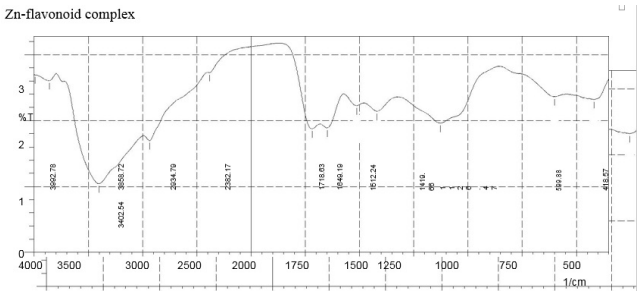

Figure 9b: FTIR Absorption Spectra for Zn-flavonoid complex from *Telfairia occidentalis* leaves.

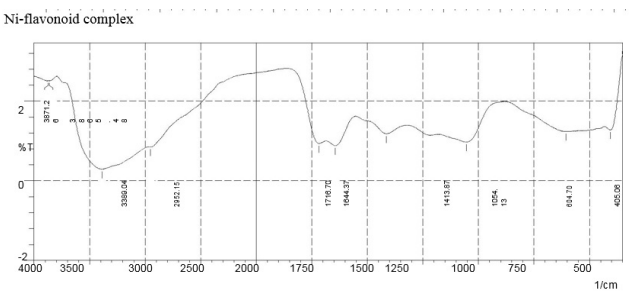

Figure 9c: FTIR Absorption Spectra for Ni-flavonoid complex from *Telfairia occidentalis* leaves.

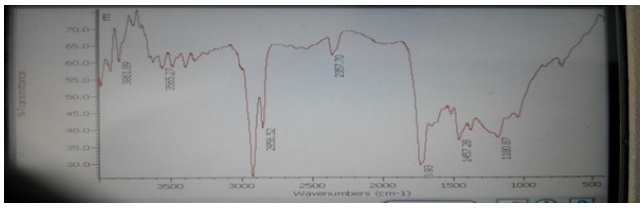

Figure 10: FTIR Absorption Spectra for flavonoid extracts from *Telfairia occidentalis* leaves.

Evidence of formation of complexes for the extracts

In the complexes spectra, the bands assigning to the carbonyl group are shifted to lower wave number in comparison with that of the free ligands as a result of its coordination [13].

The IR spectrum of the flavonoid shows a band at 1732 cm^{-1} for C=O, which reduced to 1723 cm^{-1}, 1725 cm^{-1} and 1725 cm^{-1} for Cu-flavonoid complex, Zn-flavonoid complex and Ni-flavonoid complex respectively in *Moringa oleifera*. In *Cassia tora*, the IR spectrum of flavonoid shows a band at 1727 cm^{-1} for C=O, which shifted to 1641 cm^{-1}, 1723 cm^{-1}, 1724 cm^{-1} for Cu-flavonoid complex, Zn-flavonoid complex and Ni-flavonoid complex respectively.

The IR spectrum of flavonoid shows a band 1733 cm^{-1} for C=O, and shifted to 1685 cm^{-1} for Cu-flavonoid complex, 1688 cm^{-1} for Zn-flavonoid and 1640 cm^{-1} for Ni-flavonoid complex in *Ocimum gratissimum*. The IR spectrum of flavonoid shows a band 1717 cm^{-1} for C=O, and shifted to 1640 cm^{-1} for Cu-flavonoid complex, 1712 cm^{-1} for Zn-flavonoid and 1710 cm^{-1} for Ni-flavonoid complex in *Vernonia baldwinii* while the IR spectrum of flavonoid shows a band 1723 cm^{-1} and shifted to 1645 cm^{-1} for Cu-flavonoid complex, 1718 cm^{-1} for Zn-flavonoid and 1716 cm^{-1} for Ni-flavonoid complex in *Telfairia occidentalis*. This results indicated that complexes were formed.

UV-Visible spectra of complexes

The result of the UV-Visible spectra of wavelengths 200 nm-900 nm for the different complexes of Cu-flavonoid complex, Zn-flavonoid complex and Ni-flavonoid complex from *Moringa oleifera, Cassia tora, Ocimum gratissimum, Vernonia* and *Telfairia occidentalis* are shown in Figures 11-15 and the results were in agreement with the results of Dušan and Vesna [14].

In Figure 11 the maximum absorption peak of 10 was observed at 450 nm by Ni-flavonoid complex and followed by the peak of 4.309 observed at 250 nm for Cu-flavonoid complex and the Zn-flavonoid complex has minimum absorption peak and observed at 3.386 at 245 nm. The absorption ranged from 3.386-10 was demonstrated by the complexes.

The result of the UV-Visible absorption spectra for Cu-flavonoid complex, Zn-flavonoid complex, and Ni-flavonoid complex from *Cassia tora* plant leaves extracts are shown in Figure 12. The maximum absorption peaks of 10 were observed at 220 nm, 390 nm, 410 nm, 420 nm, 430 nm and 440 nm by Zn-flavonoid complex and followed by Ni-flavonoid complex with the absorption peak of 4.381 at 445 nm and the least absorption peak was observed 3.438 at 245 nm for Cu-flavonoid complex. The ranged was 3.438-10 and 245-445 nm.

Figure 13 shows the result for the UV-Visible absorption spectra of complexes in *Ocimum gratissimum*. The maximum absorption peak of 9.999, 9.999, 9.999, 9.999, 9.999, 9.999 and were observed at 505 nm, 500 nm, 490 nm, 485 nm, 480 nm and 475 nm respectively in Cu-flavonoid complex. In Zn-flavonoid complex, the absorption peak 3.386 was observed at 245 nm while another absorption peak 10 were also observed at 510 nm, 505 nm, 495 nm, 490 nm, 485 nm, 475 nm and 450 nm in Ni-flavonoid complex.

The result for UV-Visible in Figure 14 maximum absorption spectra was observed 10 at 505 nm, 495 nm and 490 nm in Zn flavonoid complex and Cu-flavonoid complex and Ni-flavonoid complex absorption spectra were observed at 4.160 and 3.409 at 450 nm and 400 nm respectively in *Vernonia baldwinii*.

The result in Figure 15 for UV-Visible absorption spectra for complexes, Zn-flavonoid complex had the maximum absorption peak at 9.999 at 300 nm and 240 nm. The absorption peak of 4.47 was observed at 240 nm in Ni-flavonoid complex. The minimum spectrum was recorded at 3.247 at 240 nm in Cu-flavonoid complex. The ranged of the peak was 3.247-9.999 at the ranged of 240-300 nm.

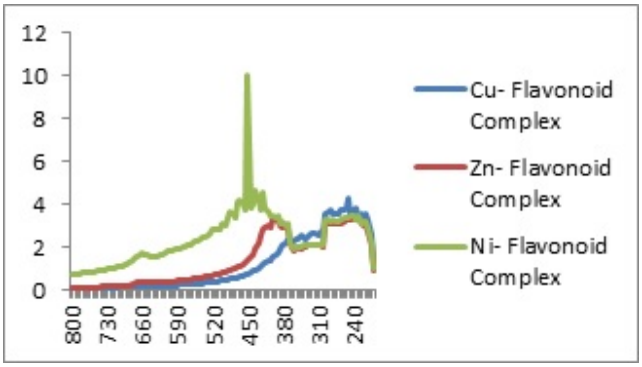

Figure 11: UV-Visible Absorption Spectra of synthesized Cu-Flavonoid Complex, Zn-flavonoid Complex and Ni-Flavonoid Complex from *Moringa oleifera* plant leaves extract.

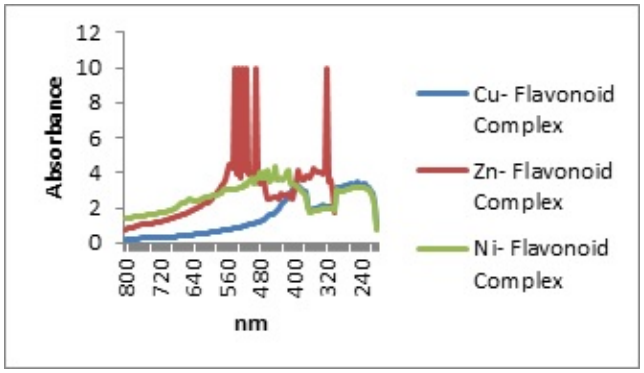

Figure 12: UV-Visible Absorption Spectra of synthesized Cu-Flavonoid Complex, Zn-Flavonoid Complex and Ni-Flavonoid Complex from *Cassia tora* plant leaves extract.

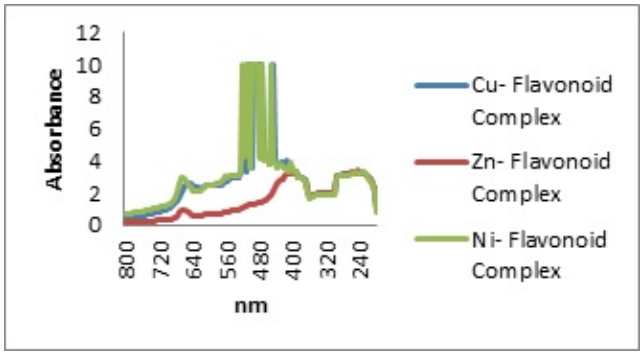

Figure 13: UV-Visible Absorption Spectra of synthesized Cu-Flavonoid Complex, Zn-Flavonoi Complex and Ni-Flavonoid Complex from *Ocimum gratissimum* plant leaves extract.

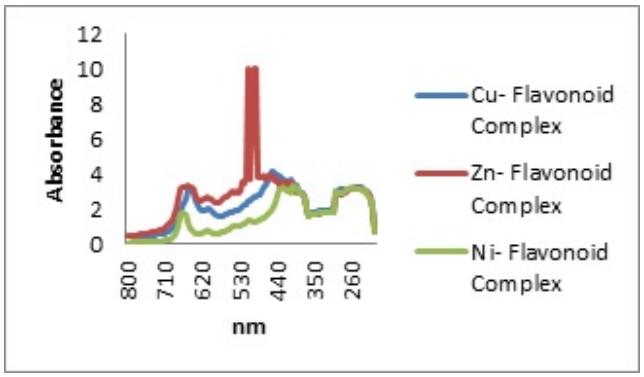

Figure 14: UV-Visible Absorption Spectra of synthesized Cu-Flavonoid Complex, Zn-Flavonoid Complex and Ni-Flavonoid Complex from *Vernonia baldwinii* plant leaves extract.

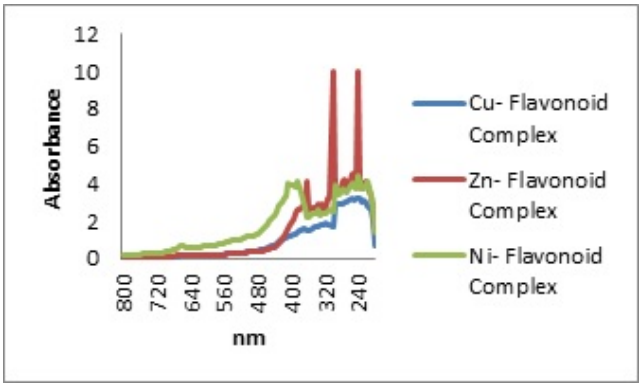

Figure 15: UV-Visible Absorption Spectra of synthesized Cu-Flavonoid Complex, Zn-Flavonoid Complex and Ni-Flavonoid Complex from *Telfairia occidentalis* plant leaves extract.

UV-Visible spectra of flavonoid extracts

The UV-Visible absorption spectra for flavonoid extracts from the study plant leaves were also determined by UV-Visible spectroscopic and shown in Figures 16-20. In *Moringa oleifera* plant extract, the maximum absorption peak was 0.873 at 370 nm and the minimum absorption peak of 0.004 at 807 nm. The maximum peak of 0.982 at 286 nm and the minimum absorption peak of 0.022 at 829 nm were observed in *Cassia tora* plant leaves extracts. The maximum peak of 0.932 at 289 nm and the minimum absorption peak of 0.009 at 802 nm were observed in *Ocimum gratissimum* leaves extracts. In *Vernonia baldwinii* leaves extracts, the maximum absorption peak was 1.252 at 289 nm while the minimum absorption peak was 0.003 at 829 nm. The plant extracts of *Telfairia occidentalis* recorded the maximum absorption peak at 0.832 at 290 nm and the minimum absorption peak was 0.020 at 804 nm. These results agreed with the results of Dušan and Vesna [14].

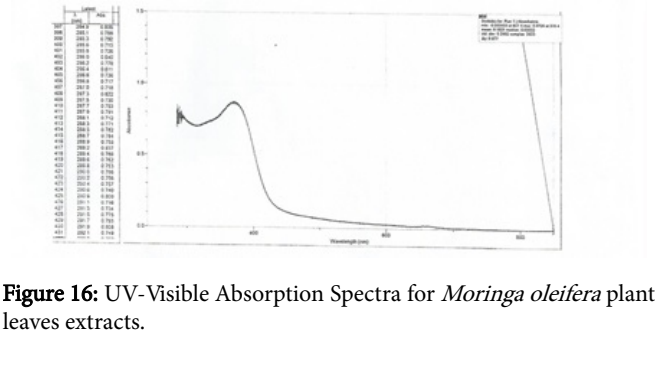

Figure 16: UV-Visible Absorption Spectra for *Moringa oleifera* plant leaves extracts.

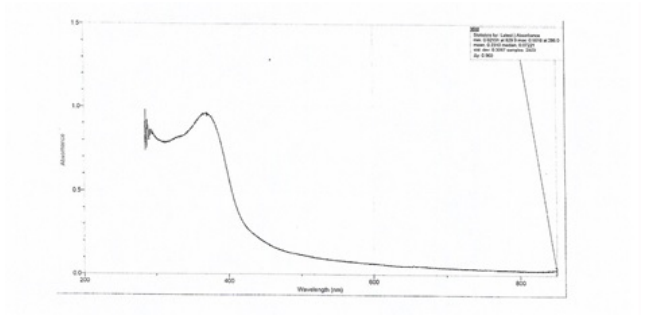

Figure 17: UV-Visible Absorption Spectra for *Cassia tora* plant leaves extracts.

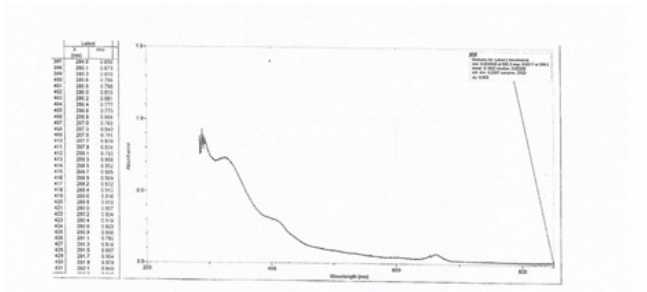

Figure 18: UV-Visible Absorption Spectra for *Ocimum gratissimum* plant leaves extracts.

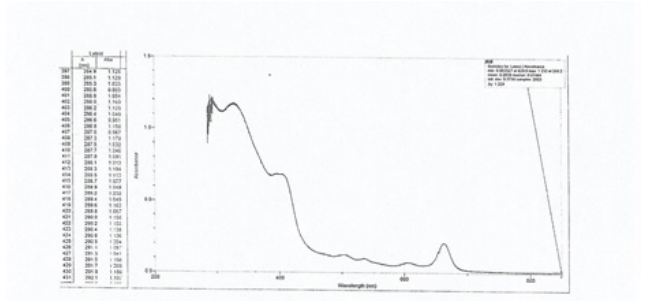

Figure 19: UV-Visible Absorption Spectra for *Vernonia baldwinii* plant leaves extracts.

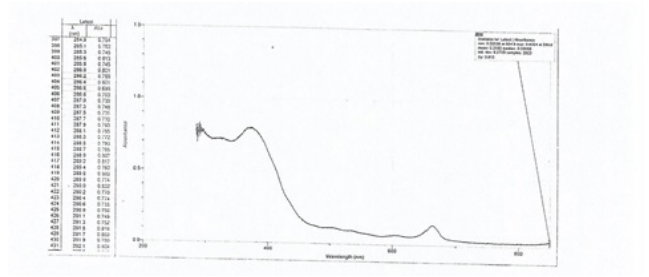

Figure 20: UV-Visible Absorption Spectra for *Telfairia occidentalis* plant leaves extracts.

Conclusion

The study established that complexes were formed between metal and the flavonoid. The results showed a significant coordination for complexes as the values of the carbonyl functional group C=O of the free flavonoid shifted to lower peak in metal-flavonoid complexes. The complexes were formed at slightly acidic condition between the pH value 3.51 to 4.65. The study presents many applications, such as the possession of higher potencies toward superoxide than the parent flavonoids. Transition metals also enhance the anti-flammatory activities of flavonoids and their cytoprotective effect against oxidative injury in isolated cell. In addition, the study shows an outstanding impact as anti-oxidants thereby making them more effective in protecting red blood cells. This research will be very helpful in discovering new drugs and products for use in agriculture, health, medicine and pharmacy.

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