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Investigating Phytochemical Properties of Camel's Foot (*Pilostigma Reticulatum)* Plant Parts Extracts for Corrosion Inhibition

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Abstract: *Corrosion is seen as a serious treat especially in industrialized countries that is why in the discipline of engineering, corrosion's destructive power over metal becomes a subject of study. Synthetic compounds utilized as corrosion inhibitors today are extremely detrimental to the environment because they are non-biodegradable and carcinogenic, and also expensive. Thus, the need for an inexpensive, non-toxic, and biodegradable corrosion inhibitor that is mostly derived from fragrant spices, herbs, and medicinal plants. The aim of this study is to investigate the phytochemical properties of Camel's Foot (Pilostigma reticulatum) plant parts extracts for corrosion inhibition. The leave, bark and root of (Pilostigma reticulatum) plant extract was formulated using maceration method before being subjected to standard phytochemical screening and quantitative phytochemical analysis procedures. The findings reveal different arrays of phytochemical compound such as carbohydrates, glycosides, flavonoids, saponins, alkaloids, Anthraquinones, and tannins, are present in all the leaves, bark and root of Camel's Foot (Pilostigma reticulatum) plant extracts. These phytochemical compounds such as tannins, flavonoids, Alkaloids and phenols exhibits inhibitory effects on metals surface. The quantitative analysis reveals that the Total tannin content (TTC) for leaves, bark and root are 110 (mg TAE/g), 62.39(mg TAE/g), 56.98(mg TAE/g), for Total Phenolic content (TPC) are 56.2 (mg GAE/g), 148.2(mg GAE/g), 41.2(mg GAE/g) respectively and Total Flavonoid Content (TFC) are 80(mg RE/g), 74.26(mg RE/g), 53.38(mg RE/g) respectfully.*

Keywords: *corrosion, corrosion inhibitor, leaf extract, piliostigma reticulatum*

1.0 INTRODUCTION

Everything that surrounds us is made of chemical compounds, whether natural or artificial chemical compounds. While some of them are steady, others are incredibly resilient, however they are all exposed to environmental interactions that has negative long-term impact on the structural performance, encompassing dependability (Raja *et al*., 2016 and Shah *et al*. 2008), in atmospheric conditions, most metals and alloys are unstable and prone to corrosion. The most significant of these alloys is steel, an iron and carbon alloy with a low carbon percentage that is widely utilized because of its affordability, accessibility, and superior mechanical qualities. Corrosion is the result of

a material's chemical deterioration, which causes the material's qualities to deteriorate (Buchweishija, 2009). The corrosion potentially affects industrial equipment, reduces the shelf life of the infrastructure assets and the quality of the environment therefore the need to control corrosion to save considerable expenses in Materials, equipment, and structure (Mohammed, 2020).

The impact of corrosion has been taken as unusual especially in industrialized countries. Numerous studies that have evaluated financial losses have concluded that industrialized nations lost 3% of their GDP due to early material degradation (Angst, 2018). In 2016, NACE International studied the implications of corrosion in countries such as India, Japan, Kuwait, United Kingdom and the United State to assess the cost of global corrosion. It was estimated that the total cost of corrosion was about US$2.5 trillion, or 3.4% of global GDP. Corrosion engineering is the science of preventing and controlling corrosion and when effectively applied could save up to $9.3 billion in cost (Roberge 2020). It is possible to reduce corrosion costs by 15–35% by using current corrosion management practices and techniques, which include organic corrosion inhibitors (Koch, 2016).

According to Uzorh (2013). Using inhibitors is one of the most practical strategies to stop corrosion, especially in acidic environments to prevent unexpected metal breakdown and acid consumption (Desai and Kapopara, 2009). The majority of these inhibitors are organic substances that exhibit notable levels of inhibitory efficacy and contain nitrogen, sulfur, and oxygen. (James and Akaranta, 2011; Bhajiwala and Vashi, 2001). The search for green corrosion inhibitors has been sparked by the environmental toxicity of organic corrosion inhibitors. In addition to being biodegradable, free of heavy metals or other harmful substances, and ecologically acceptable, plant-based corrosion inhibitors are also affordable, easily obtainable, and renewable. Research on the anti-corrosion properties of tannins, alkaloids, organic compounds, amino acids, and plant-based organic colors is interesting (Basu and Rani, 2012). There are researches on green corrosion inhibitors that efficiently inhibits corrosion on metal surface showing excellent results for example hybridization of neem leaf and moriga leaf (Aji, *et al.,* 2016), potential of phytochemical properties of ziziphus Mauritania (magariya) leaf extract for corrosion inhibition (Usman *et al.,* 2024), leptadenia hasasta(yadiya) leaves extract (Maina, et al., 2021 and Maina et al., 2022), polyalthia longifolia leaves extract (Zubairuet al., 2021), locust bean husk, cashew, neem, mahagony, and acacia nolitica pods (Yawas 2005), Leptadenia pyrolechnica's stem, fruit, and root (Singh et al. 2015) and many others. An overview of research on corrosion inhibition provides details about the nature and extent of studies carried out in this field. Among other corrosion control measures, organic inhibitors have been the focus of corrosion control and preventive strategies due to the inherent health and safety concerns. Notably, research has concentrated on environmentally acceptable and renewable materials (Sharmer et al., 2011; Sharmer et al., 2010).

The plant called camel's foot (*Piliostigma Reticulatum*), which is also referred to as Kalgo in Hausa, is native to the Sahel-Sudanian region of Africa, extending from Senegal, Mauritania, and Sudan to Mozambique (Fibres, 1846) and are also widely distributed in northern Nigeria, it belongs to the Fabacea plant family. The aim of this study is to investigate the phytochemical properties of camel's foot *(Piliostigma reticulatum)* plant parts extract for corrosion inhibition of mild steel. The objectives of this study are to formulate the plant extract from carmel's foot (*Piliostigma reticulatum) (kalgo)* plant parts (leaf, root and stem bark and conduct phytochemical analysis of the plant extract

2.0 MATERIALS AND METHOD

This section outlines the various materials and equipment used for this research work, as well as the experimental procedures.

2.1 Materials and Equipment

Fresh leaves, root and stem bark of *Piliostigma reticulatum* plant were collected from around University of Maiduguri campus. Solvents such as Distilled Water, Ethanol and Acetone were used for extract preparation at the Pharmacy Department laboratory University of Maiduguri, reagents such as Folin Ceocalteu reagent, ruttin reagent, garlic acid, tannic acid, sodium nitrate, aluminum chloride, ferric chloride, NaOH, silica gel, Molish, Mayer and Fehlings reagent were used for phytochemical screening purchased from Emmicon Scientific supplies Chemical store, Adjacent Mara-Zain Hotel Bama Road, Maiduguri, Borno State, grinder, Analytical mass balance (Newacalox: Mode 8068, 100×0.001g) for measuring the mass samples, desiccator used for drying and keeping the prepared sample air tight, Conical flax, Water Bath (Gulfex Medical and Scientific: HH-420), Separating funnel and filter paper: for filteration of ethanol and plant parts from their chaff, UV-VIS Spectrophotometer UV752(D) PEC Medical USA, Cuvet, micro pipet, beakers: For Carrying out absorbance test for the quantitative phytochemical analysis

2.2 Methods

2.2.1 Plant Collection, Identification and Preparation of Bio- Extract

The root, back and leaves of Camel's foot (*Piliostigma reticulatum* Camel's*)* plant was collected from within University of Maiduguri. The plant was then identified by Dr. Cletus A. Ukwubile of the Department of Pharmacognocy, Faculty of Pharmacy University of Maiduguri. It was given a Voucher number UMM/FPH/4/FAA/010 which is then deposited in the faculty's herbarium. The plant family is Fabacea, it was then washed with tap water to remove dirt and then shade dried for one week to remove moisture content. The plant part was separately pulverized into fine powder and then weighed on the analytical mass balance to 700g as reported by loto et al., (2012). Weighing out 850g of the powdered leaves, we put them in a thimble. After that, the thimble was placed into a maceration extractor's extraction chamber. Using a measuring cylinder, the exact volume of ethanol (20000ml) was measured and then added to the extraction chamber. The components were allowed to extract over the course of two days. Following the two-day extraction period, the samples were filtered, and the filtrates that were left over were then subjected to distillation using the proper distillation apparatus in order to extract the ethanol.

2.3 Phytochemical Analysis

The phytochemical analysis of the root, back and leaves extract was carried out using standard methods described by Trease and Evans (2002) and Gauhar et al., (2017) in the Pharmacy Department Laboratory, University of Maiduguri

2.3.1 Qualitative Phytochemical Analysis (Inference)

The phytochemical analysis was conducted to identify the phytochemical constituent in the root, back and leave of the Camel's foot (*piliostigma reticulatum*) plant extract

2.3.1.1 Test for Carbohydrate

Molish's Test

In a test tube containing 0.5 g of the extract dissolved in 5 ml of water, a few drops of Molish's reagent were added. Following a two-minute incubation period, 1 milliliter of tetraoxosulphate (VI) acid was added to the mixture and diluted with 5 milliliters of distilled water. The presence of carbohydrates is indicated by the formation of a red or dim violet color at the interface between the two layers. (Trease and Evans, 2002)

2.3.1.2 Test for Tannin

Braymer's Ferric Chloride test

After adding 10 milliliters of distilled water to 0.5 grams of extract, the liquid was filtered. A few drops of a 10% ferric chloride solution were added to the additional aqueous solution. The presence of tanning is indicated by a blue-green precipitate. (Trease and Evans 2002)

2.3.1.3 Test for Saponin

Frothing Test

After a little amount of the extract was dissolved in distilled water for ten minutes, the mixture was rapidly shaken for thirty seconds, and the mixture was let to stand. The formation of honeycomb, which persisted even after heating, is evidence of the existence of saponin.

3.3.1.4 Test for Flavonoid

Ferric Chloride test

A green-blue coloring denotes the presence of phenolic hydroxyl groups. 0.5 g of the extract was heated with 5 ml of distilled water, and the filtrate was filtered to 2 ml. A few drops of 10% ferric chloride solution were then added.

Shinoda's Test

Three pieces of magnesium chips were added to the field trip together with five grams of the extra code dissolved in five milliliters of ethanol, wormed, and then filtered. A few drops of hydrochloric acid were added after that, and the presence of flavonoids was indicated by the reddish-purple coloration (Usman, et al., 2009).

2.3.1.5 Test for Glycosides

Lieberman Burchard's test

0.5 g of the extract was mixed with 2 ml of acetic anhydride. After allowing the mixture to cool in ice, 3 milliliters of the concentrated tetraoxosulphate (VI) acid were cautiously added. When a color changes from violet to bluish-green, glycoside is present. In 2019, Babakura et al.

Salkowski's Test (Test for steroidal nucleus)

0.5g of the extract was mixed with 2 ml of chloroform, and a lower layer was formed by carefully adding 3 ml of tetraoxosulphate (VI) acid at the test tube's side. A reddish-brown hue that appears at the contact suggests that a steroidal ring is present (Audu et al., 2014).

2.3.1.6 Borntrager's (Test for free Anthraquinones)

To 0.5g of the extract, 10 mil of benzene was added, and the mixture was agitated. After the mixture was filtered, 5 milliliters of a 10% ammonia solution were added, and the mixture was shaken again. Anthraquinones are indicated by the emergence of a pink color in the lower interface (Trease and Evans, 2002).

2.3.1.7 Test for Alkaloids

Dragendoff's, Mayer's, and Wagner's Test

5 ml of 1% aqueous hydrochloric acid was added to 0.5 g of the extract, which was then filtered into three equal portions in a test tube. In the first portion, a few drops of Dragendoff's reagent were added, and the appearance of orange red precipitate was considered to be an indication of the presence of alkaloids. In the second portion, a few drops of Mayer's reagent were added, and the appearance of buff colored precipitate was an indicator of the presence of alkaloids. Finally, a few drops of Wagner's reagent were added to the top portion, and the appearance of a dark brown precipitate was an indication of the presence of alkaloids (Bakura et al., 2019).

2.3.2 Quantitative Phytochemical Estimation

To identify the secondary metabolites of the plant, such as total phenolic content (TPC), total tannin content (TTC), and total flavonoid content (TFC), Total Saponin (TSAP), the extract was put through a quantitative phytochemical assay.

2.3.2.1 Estimation of Total Phenolic Content (TPC)

Using the Folin-Ciocaltaeu test, the total phenolic content of the dry extracts was determined. Following the dissolution of 10 mg of extract in 10 milliliters of deionized distilled water (1 mg/ml), the mixture of 5 grams of sodium carbonate and 25 milliliters of distilled water was added. After five minutes, 2 ml of Folin Ciocalteu's phenol reagent was added, and everything was well combined. The mixture was left in the dark at 23 0C for 90 minutes. Next, using a UV Spectrophotometer, the absorbance at 765 nm was measured. A series of reference standard solutions of garlic acid (25, 50, 100, 400, and 800 µg/ml) were made in the same way as previously reported. By creating a solution of Gallic acid, the calibration curve was extrapolated to yield the total phenolic content. Three separate measurements of the phenolic chemicals were made. The TPC was measured using water as the blank and represented as milligrams of Gallic acid equivalents (GAE)/g of dried material. (Kavitha and Indira, 2016)

2.3.2.2 Estimation of Total Tannin Content (TTC)

We used the Folin-Ciocalteu technique to determine the tannin content. A volumetric flask (10 ml) was filled with 10 ml of distilled water, 0.2 ml of Folin-Ciocalteu phenol reagent, 5 g of sodium carbonate solution, and approximately 10 ml of the sample extract. The flask was then diluted with 25 ml of distilled water. After giving the mixture a good shake, it was left at room temperature for half an hour. Tannic acid reference standard solutions (10, 20, 40, 80, and 160 µg/ml) were made using the same technique as previously mentioned. Using a UV/visible spectrophotometer, the absorbance of the test and standard solutions was measured at 760 nm in relation to the blank. Three separate measurements of the tannin content were made. The amount of tannin in the sample was stated as milligrams of tannic acid equivalents per gram of dried material. (Kavitha and Indira, 2016)

2.3.2.3 Estimation of Total Flavonoid Content Procedure

Preparation of standard solution (Ruttin Reagent)

1 mg Ruttin was measured and added distilled water to a 10 ml volumetric flask to make it up to 10 ml. One gram of sodium nitrate ($NaNO_3$) diluted in ten milliliters of distilled water was added to the aforementioned Ruttin solution (1 mg/ml) and thoroughly mixed. 1g of a 10% aluminum chloride solution was added after 5 minutes. With distilled water, the entire volume was brought to 10 milliliters. Water served as the blank. After thoroughly blending the solutions, the UV-Visible spectrophotometer was used to measure the absorbance at 510 nm in comparison to the blank. Using different Ruttin concentrations and their matching absorbance, a standard graph was plotted. Preparation of sample solution

The methodology outlined by Kavita and Indira (2016) was used to assess the total flavonoids content of each plant extract. Using this procedure, 10 mg of sample was combined with 10 ml of distilled water, and then 1 g of $NaNO_2$ solution (10%) was added with the distilled water. 1 mg of 10% $AlCl_3$ solution was added after 5 minutes, and the solution was diluted. After the mixture had been well combined, absorbance at 510 nm was measured in comparison to a blank. Ruttin equivalents, or mg Ruttin/g dried extract, were calculated using a standard curve of Ruttin. Three separate measurements of the flavonoid content were made (Kavitha and Indira, 2016).

3.0 RESULTS AND DISCUSSION

Plate 1: Phytochemical screening **Plate 2**: Rotary Evaporator **Plate 3:** Bark, Leave and Bark extract.

Phytochemicals Screening

Table 1 presents the results of the phytochemical analysis of the leaf extracts of *piliostigma reticulatum* plant parts (leaves, root and bark). The phytochemical examination of all the leaves, root and stem extracts reveals the presence of organic compounds (such as Carbohydrates Glycosides, saponins, Cardiac glycosides, tannins, steroids, and flavonoids) in all the three plant parts. The presence of these phytochemicals in the leaf extracts of *piliostigma reticulatum* plant parts (leaves, root and bark) suggests its potential as a corrosion inhibitor. The identified compounds possess properties such as antioxidant activity, film formation, metal chelation, and surface protection, which are associated with inhibiting the corrosion process. This indicates that *piliostigma reticulatum* plant parts (leaves, root and bark) may have the ability to mitigate metal corrosion effectively.

Table 1: Qualitative Phytochemical Analysis of Plant Extracts

1	Carbohydrates	Molisch	+	+	+
2	Anthraquinones	Bontrager's	+	+	+
3	Glycosides	Lieberman Burchard's test	+	+	+
		Salkowski's Test (Test for steroidal nucleus)	+	+	+
4	Saponins	Frothing	+	+	+
5	Tannins	Braymer's Ferric chloride	+	+	+
6	Flavonoids	Shinoda's test	+	+	+
		Ferric Chloride	+	+	+
7	Alkaloids	Dragendorff'd	+	+	+
		Mayer's	+	+	+
		Wagners	+	+	+

+ =Present

These phytochemical compounds exhibit resistance to corrosion on metal surface, the organic substance tannin combines with iron (III) to create complexes (Singh *et al.,* 2010). When saponin and flavonoids are present on metal, they produce a complex affinity that works well as a corrosion inhibitor. This indicates that all the presence of these phenolic compounds on metal surface will provide strong adsorption molecules of *piliostigma reticulatum* plant parts extracts film. The presence of saponin and flavonoid on metal form complex affinity that is effective for corrosion inhibitor performance. These phytochemicals have the capacity to enhance the process of corrosion inhibition of mild steel in acidic medium. The presence of these compounds has been reported to promote the corrosion inhibition of mild steel in aggressive acid media (Umoren et al., 2006). Moreover, it is recommended fact that the adsorption properties of the plant extract are directly attributed to the presence of various chemical constituents. In this study, the phytochemical determination of the plants extracts is very essential. However, alkaloids, flavonoids and tannins constitute one of the classes of natural products, being synthesized by many organisms. The compound possesses at least one hetero atom in their molecule which is recognized to inhibit corrosion. Nevertheless, phytochemical compounds contain oxygen and nitrogen molecule which possess lone pair of electrons that may facilitate the formation of dative bonds acting as center for adsorption, thus creating a barrier between steel surface and the corrosive media (Rani and Basu, 2012).

Table 2: Quantitative Phytochemical Analysis

S/N	Phytochemical Constituents	Composition of Leaves	Composition of Back	Composition of Root
1	Total Phenolics Concentration (mg GAE/g)	56.2	148.2	41.2
2	Total Tanins Concentration (mg TAE/g)	110	62.39	56.98
3	Total Flavonoids (mg RE/g)	80	74.26	53.38

Table 2 presents the quantitative analysis of the leaves, root and back extract of *Piliostigma reticulatum* plant Extract for Total Phenolics Concentration (TPC), Total Tanins Concentration (TTC) and Total Flavonoids Concentration (TFC) using spectrometric method. Phenolic compounds are well known for being potent antioxidants that can break chains. Phenols are essential component of plants because of their ability to scavenge free radicals due to their hydroxyl group (Sharmer 2021). Total Phenols are important in regulating oxidation. Flavonoids are a group of secondary metabolites that persist in plant inform of polyphenolic glycocides linkages or molecules, flavonoids also have antioxidant properties and chelating such as in tanins which are chelators of metals ions. These characteristics make them valuable in inhibiting metal corrosion by preventing the initiation and propagation of corrosive reactions. These phytochemical compounds, have shown potential as corrosion inhibitors due to their ability to form protective films on metal surfaces, thereby reducing the likelihood of corrosion (Gunavathy 2013)

The results showed that the *piliostigma reticulatum* plant parts contains potent amount of phenolic, tannin and flavonoids compounds which can inhibit metallic corrosion. The quantitative analysis reveals that the Total tannin content (TTC) for leaves, bark and root are 110 (mg TAE/g), 62.39(mg TAE/g), 56.98(mg TAE/g), for Total Phenolic content (TPC) are 56.2 (mg GAE/g), 148.2(mg GAE/g), 41.2(mg GAE/g) and Total

Flavonoid Content (TFC) are 80(mg RE/g), 74.26(mg RE/g), 53.38(mg RE/g) respectfully. The presence of these phytochemicals in reasonable quantity shows that all the leaves, bark and root of Camel's Foot (*Pilostigma reticulatum*) plant have the ability to mitigate metal corrosion effectively if well harness and utilized. Therefore, there is need to conduct corrosion inhibition studies to validate the efficacy of these extracts in various corrosive environment. However, it is crucial to note that further research is needed to confirm the effectiveness of *piliostigma reticulatum* as a corrosion inhibitor. Empirical evidence to support and quantify the inhibitory potential of *piliostigma reticulatum* plant parts extracts would be obtained through specific corrosion inhibition research carried out in pertinent corrosive conditions.

4.0 CONCLUSION

This study investigates the phytochemical properties of leaf, bark and root extracts of carmel's Foot (Piliostigma reticulum) plant. From the research, the following conclusions were drawn;

I. The extracts were successfully obtained from the Leaves, Barks and Roots of Camel's foot (*Piliostigma reticulatum*) using maceration method.

II. The extracts were subjected to standard phytochemical screening and quantitative phytochemical analysis procedures where the findings reveal different arrays of phytochemical compound such as carbohydrates, glycosides, flavonoids, saponins, alkaloids, Anthraquinones, and tannins, are present in all the leaves, bark and root of Camel's Foot (*Pilostigma reticulatum*) plant extracts. These phytochemical compounds such as tannins, flavonoids, Alkaloids and phenols are known to exhibits inhibitory potential effects on metals surface. These identified compounds exhibit metal chelation, antioxidant, film formation and surface protection properties that inhibits corrosion of metal.

III. The quantitative analysis reveals that the Total tannin content (TTC) for leaves, bark and root are 110 (mg TAE/g), 62.39(mg TAE/g), 56.98(mg TAE/g), for Total Phenolic content (TPC) are 56.2 (mg GAE/g), 148.2(mg GAE/g), 41.2(mg GAE/g) and Total Flavonoid Content (TFC) are 80(mg RE/g), 74.26(mg RE/g), 53.38(mg RE/g) respectfully. The presence of these phytochemicals in reasonable quantity shows that all the leaves, bark and root of Camel's Foot (*Pilostigma reticulatum*) plant have the ability to mitigate metal corrosion effectively if well harness and utilized. Therefore, there is need to conduct corrosion inhibition studies to validate the efficacy of these extracts in various corrosive environment.

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