

HYBRIDIZATION OF PLANT EXTRACTS OF CASHEW (CASHUT) AND ZIZIPHUS SPINA-CHRISTI (KURNA) AS CORROSION INHIBITORS

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ABSTRACT

Corrosion poses significant challenges across various industries, necessitating the development of effective inhibitors for its prevention. This study aims to investigate the potential of plant extracts as corrosion inhibitors, focusing on cashew and Ziziphus spina-christi leaves due to their eco-friendliness and availability. The objectives include extracting and analyzing phytochemical compounds from these leaves and evaluating their corrosion inhibition efficiency. Results revealed that both cashew and Ziziphus spina-christi extracts contain compounds with corrosion inhibition properties. The hybrid extract showed promising efficiency, with corrosion inhibition levels reaching up to 80.14%. Phytochemical analyses confirmed the presence of compounds such as tannins, flavonoids, and alkaloids, known for their corrosion inhibition capabilities. Recommendations include further evaluation of corrosion inhibition efficiency, optimization of extract concentrations, and investigation of long-term stability. This study underscores the potential of plant extracts as eco-friendly corrosion inhibitors, offering insights for practical industrial applications.

Keywords: corrosion inhibitors, cashew leaves, ziziphus spina-christi leaves, hybridization of plant extracts

1 INTRODUCTION

Corrosion refers to the deterioration of metal due to exposure to corrosive environments, either through direct chemical reactions or electrochemical processes in contact with aqueous corrosive surroundings. It poses significant concerns related to safety, preservation, and economics across multiple fields such as chemical, automotive, metallurgical, natural, and medical engineering. It particularly affects the design of diverse mechanical components, varying in size, function, and expected lifespan [1, 2]. Corrosion can cause life-threatening damage to metal and alloy structures causing financial punishment in terms of renovation, replacement, product losses, safety and environmental pollution [3]. The deterioration of metal can lead to increased loss of productivity due to the impaired functioning of corroded tools and the contamination of key industrial products, such as chemicals, with the by-products of aqueous corrosion. Product leakage further reduces efficiency [4]. Globally, corrosion leads to an economic loss of approximately 2.5 trillion US dollars, accounting for nearly 3.4% of the total GDP (2013). However, by effectively implementing existing technologies for corrosion prevention, it is possible to reduce the cost of corrosion by 15-35%, amounting to a significant range of 375-875 billion US dollars [5, 6]. The significant costs of corrosion are also experienced by the oil and gas sector [7] as well as the food and agro-processing

industries of Nigeria [8]. If the materials affected by corrosion are not treated, it can result in equipment failures for the industry [9]. Due to these harmful effects, corrosion is an unattractive observable fact that must be prevented. Prevention would be more realistic and practicable than complete eradication [10]. The prevention of metals against corrosion has attracted much attention globally as a result of huge losses of natural resources and finances that are sustained annually all over the world due to corrosion [11]. Development of corrosion inhibitors is necessary in order to protect metals against degradation through electrochemical and environmental attacks [12]. Corrosion inhibitors are substances that are added in small amounts on metal surfaces or are added to the corrosive medium, reducing the tendency to be affected by corrosion. The use of common corrosion inhibitors is sometimes limited, since these are based on dangerous substances for human health, such as chromium-based treatments [13]. It has been established that among all the option available for preventing metals (industrial installations) against degradation, the use of inhibitors is one of the best [14]. Practically, corrosion inhibitors are derived or synthesized and the essential requirements are possession of heteroatom (to facilitate adsorption), aromaticity, and suitable functional groups and conjugated or pie-electron bond [15]. Several organic and inorganic compounds have met these conditions but recently, additional concerns are centred on the environmental requirements which aimed at replacing toxic and expensive corrosion inhibitors with their green counterparts [16]. According to [17], green corrosion inhibitors are cheap, biodegradable, easily accessible and environmentally friendly. Most corrosion green inhibitors currently in use products or extracts of animals and plants. *Cashew (Cashut) and Ziziphus spani-Christ (Kurna)* are natural sources that possess various beneficial properties, including antioxidant and antimicrobial activities. These properties suggest their potential as corrosion inhibitors. Exploring the effectiveness of these extracts as corrosion inhibitors can provide valuable insights into their applicability in industrial settings. To combat corrosion various techniques have been developed including the use of corrosion inhibitors. Corrosion inhibitors are substances that when added to a corrosive environment can reduce or suppress the corrosion rate of metals. Conventional corrosion inhibitors often contain toxic and environmentally harmful components, prompting researchers to explore alternative and eco-friendly options. In light of the need for environmentally sustainable corrosion inhibition strategies, this study contributes to the ongoing exploration of alternative solutions by investigating the corrosion inhibition potential of plant extracts from cashew and *Ziziphus spina-christi* leaves.

2 MATERIALS AND METHODS

2.1 Materials and Equipment

Fresh leaves of *Cashew and Ziziphus Spina-Christi* plants as shown in plate 1. Collected leaves from around University of Maiduguri Campus on 27th August, 2023. Commercial grade ethanol was purchased from a local store in Maiduguri Metropolis. Other materials include distilled water, analytical grade hydrochloric acid and acetone. The equipment used includes X-ray fluorescent (XRF), Spectrophotometer, blender, desiccator, sieve, beakers, test tube, funnels, sensitive digital scale (with precision of 100×0.001g), measuring cylinder (100ml and 10ml), filtration equipment, maceration extractor, mild steel coupons, dropper, hand glove, corrosion reaction container, sample bottles, brush and Rotary evaporator machine. Plate 1 shows *Ziziphus spina-christi* leaf and cashew leaf.



Ziziphus Spina-christi leaf (A) Cashew leaf (B)

Plate 1. Ziziphus and Cashew leaf

2.1.1 Acetone

500 ml of acetone. Acetone is the organic compound with the formula $(\text{CH}_3)_2\text{CO}$. It is colourless, volatile, flammable liquid and is the simplest and smallest ketone. Acetone is miscible with water and serves as an important solvent in its own right and was used for cleaning the coupons.

2.1.2 Brush

A brush is a common tool with bristles, wire or other filaments. It generally consists of a handle or block to which filaments are affixed in either a parallel or perpendicular orientation, depending on the way you brush is to be gripped during use. The material of both the block and bristles or filaments was chosen to withstand hazards of its intended use, such as corrosive chemicals, heat or abrasion. It is used for cleaning surface finishing and for many other purposes.

2.2 Methods

2.2.1 Preparation of the leaves sample

The freshly collected leaves of *Cashew* and *Ziziphus Spina-Christi* were cleansed by washing them with distilled water to remove any dust or debris. Subsequently, by using phytochemical analysis standards, the leaves were chopped into smaller fragments and left to undergo a drying process, living for 10 days at room temperature, resulting in a significant reduction of moisture content by 91%. Once dried, the leaves were finely ground into a powder to facilitate the extraction process. Plates 2 and 3 shows the drying and weighing processes of the samples.



Process of drawing cashew (A)

Process of draying ziziphus (B)

Plate 2. Drying process



250g powder of cashew (A)



250g powder of ziziphus (B)

Plate 3. weighing process

2.2.2 Extraction

According to [15] 500g of the powdered leaves was weighed; 250g for each plant leaves were grounded into powdered form then measured and placed into a glass container and solvent was added shaken for maceration extractor. A volume of 2000ml of ethanol was carefully measured using a measuring cylinder and poured into the extraction chamber, allowing the constituents to extract over a period of three days (72 hours), then during the hours the container was shaken time to time to ensure complete extraction. After the three-day extraction period, the samples were filtered, and the resulting filtrates underwent distillation using appropriate distillation equipment to remove the ethanol from the samples for the following tests according.

2.3 Phytochemical Screening Method

Phytochemical screenings are preliminary tests conducted to detect the presence of both primary and secondary metabolites in an extract. Phytochemical analysis of the extracts was carried out at Pharmacognosy Laboratory, Faculty of Pharmacy, University of Maiduguri. The qualitative analysis described below was used to detect the presence of alkaloids, glycosides, flavonoids, tannins, saponins, carbohydrates, anthraquinones, and cardiac glycosides following the standard procedures as used similar findings was reported by [18, 19, 20]. Secondary metabolites are the classes of compound which are known to show curative against several ailments in man, and therefore could explain the use traditional of medicinal plant for the treatment of some illness. There are chemical compounds (phenolic compounds, alkaloids, terpenoids, steroids, quinones, saponins, etc.) with complex structure and with more restricted distribution than primary metabolites. They are not indispensable for the plant that contains them; at least their metabolic functions have not been discovered yet.

2.3.1 Test for Tannins

10 ml of bromine water was added to the 0.5g aqueous extract. Few drops of 1% ferric chloride solution were then added. Occurrence of a blue-black, green or blue-green precipitate showed the presence of tannins.

2.3.2 Test for Cardiac glycosides

0.5g aqueous extract was dissolved in 2ml of chloroform tetraoxosulphate (IV) acid to form a lower layer. Appearance of a reddish- brown colour or yellow at the interface was an indication for the presence of a steroidal ring (i.e., aglycone portion of cardiac glycoside) or methylated sterols.

2.3.3 Test for Saponins

The extract, weighing one gram, was boiled with 5ml of distilled water. The resulting mixture was then filtered, and the filtrate was divided into two equal portions. In the first portion, approximately 3ml of distilled water was added, followed by shaking for approximately 5 minutes. The presence of persistent frothing upon warming is considered as evidence for the presence of saponin. In the second portion, 2.5ml of a mixture consisting of equal volumes of Fehling's solution A and B was added. The appearance of a brick-red precipitate indicates the presence of saponin.

2.3.4 Test for Flavonoids

The extract 0.5g was boiled with 5 ml of distilled water and then filtered. To 2ml of the filtrate and few drops of 10% ferric chloride solution was then be added. A green-blue or violet colouration indicated the presence of flavonoids similar findings was reported by [21].

2.3.5 Test for Alkaloids

The extract 0.5g was stirred with 5 ml of 1% aqueous HCL on water bath and then filtered. 3ml of the filtrate was divided equally added into 3 portions in a test tube. To the first portion, few drops of Dragendoff's reagent were added. The occurrence of orange red precipitate was considered as presence of alkaloids. To the second, 1ml of Meyer's reagent was added and appearance of buff-coloured precipitate was an indication for the presence of alkaloids, to the third portion, few drops of wagner's reagent were added and a dark-brown precipitate indicates the presence of alkaloids similar finding was reported by [22].

2.3.6 Test for Glycosidess

To the extract 0.5g 2 ml of acetic anhydride was added. The mixture was cooled in ice and then 3ml of concentrated tetraoxosulphate (VI) acid was added carefully, colour development from violet to bluish-green indicates the presence of glycoside similar findings was reported by [22].

2.3.7 Test for Carbohydrate

The extract 0.5g was dissolved in 5ml distilled water in a test tube. To the mixture, few drops of the molish's reagent was added, and then followed by 1 ml of concentration, tetraoxosulphate (VI) acid by the side of the test tube. The mixture was allowed to stand for two minutes and then diluted with 5ml of distilled water. Formation of red or dull violet colour at the interphase of the two layers indicated the presence of Carbohydrate similar findings was reported by [21].

2.3.8 Test for Anthraquinones

Small portion of the extracts was shocked with 10ml of benzene and filtered. 5 ml of 10% of ammonia solution was added to the filtrate and stirred. Pink-red or violet colour was observed indicate the presence of free anthraquinones.

3 RESULTS AND DISCUSSION

3.1 Phytochemical Analysis

The phytochemical analysis of *cashew* leaf extract indicates the presence of a diverse range of bioactive compounds with potential corrosion inhibition properties as shown in Table 1. Anthraquinones, identified through the borntaser test, are known for their antioxidant properties. In the context of corrosion inhibition, antioxidants can mitigate the impact of free radicals, hindering oxidative reactions that contribute to corrosion. The positive result in the borntaser test suggests that the *cashew* leaf extract contains anthraquinones, potentially enhancing its ability to inhibit metal corrosion as reported by [20]. Cardiac glycosides, as indicated by positive results in keller killiani, salkowski, and legal's tests, are compounds with established medicinal properties. In the realm of corrosion inhibition, these glycosides might contribute by forming a protective layer on the metal surface. Preventing corrosive agents from reaching the metal and slowing down the corrosion process. The multiple positive results further strengthen the hypothesis that the *cashew* leaf extract possesses corrosion inhibition potential. Flavonoids, identified through shinoda's test and Sodium hydroxide test, are recognized for their antioxidant capabilities. These compounds can form a protective film on the metal surface, impeding the progression of corrosion. The positive results in the tests provide evidence of the presence of flavonoids in the *cashew* leaf extract, supporting the notion that it may serve as an effective corrosion inhibitor. Similarly, tannins, revealed by the positive result in Braymer's test, are polyphenolic compounds known for their antioxidant properties which is in line with the ones reported by [16]. In the context of corrosion inhibition, tannins can form complexes with metal ions, preventing their interaction with corrosive agents. The detection of tannins in the *cashew* leaf extract suggests a potential mechanism for corrosion protection. Alkaloids have been associated with the formation of protective layers on metal surfaces. This characteristic can contribute to corrosion inhibition by hindering the corrosive attack on the metal. The positive results in multiple alkaloid tests suggest that the *cashew* leaf extract may indeed possess corrosion inhibition properties through the presence of alkaloids. Saponins, as indicated by positive results in the frothing and steroid tests, possess surfactant properties. In the context of corrosion inhibition, saponins may form a protective film on the metal surface, reducing the corrosive impact. The positive results in the tests suggest that saponins in the *cashew* leaf extract could play a role in inhibiting metal corrosion. While carbohydrates, identified through the Molisch test, may not directly contribute to corrosion inhibition, they could potentially act as reducing agents or stabilizing agents for other corrosion inhibitors present in the extract. Overall, the phytochemical analysis provides valuable insights into the composition of *cashew* leaf extract, highlighting its potential as a corrosion inhibitor with a diverse array of bioactive compounds. The Phytochemical analysis of leaf extracts of *Cashew* is presented in Table 1.

Table 1. Phytochemical analysis of leaf extracts of Cashew

S/N	Phytoconstituents	Test	Results
1	Anthraquinone	Borntraser test	+
		Keller killiani test	+
2	Cardiac glycosides	Salkowski test	+
		Legal's test	+
3	Flavonoids	Shinoda's test	+
		Sodium hydroxide test	+
4	Tannins	Braymer's test	+
5	Alkaloids	Wagner's test	+
		Meyer's test	+
		Dragendoff's test	+
6	Saponins	frothing test	+
		Steroid test	+
7	Carbohydrate	Molisch test	+
8	Glycosides		+

The results of the phytochemical analysis of the leaf extracts of *Ziziphus Spina-Christi* are likewise presented in Table 2. It can be observed all the phytoconstituents tested are positive similar to the results in Table 1, while table 3 shows quantitative Phytochemical Analysis of the Cashew and *Ziziphus Spina-Christi* leaves.

Table 2. Phytochemical analysis of leaf extracts of *Ziziphus Spina-Christi*

S/N	Phytoconstituents	Test	Results
1	Anthraquinone	Borntraser test	+
		Keller killiani test	+
2	Cardiac glycosides	Salkowski test	+
		Legal's test	+
3	Flavonoids	Shinoda's test	+
		Sodium hydroxide test	+
4	Tannins	Braymer's test	+
5	Alkaloids	Wagner's test	+
		Meyer's test	+
		Dragendoff's test	+
6	Saponins	frothing test	+
		Steroid test	+
7	Carbohydrate	Molisch test	+
8	Glycosides		+

Table 3. Quantitative Phytochemical Analysis of the Cashew and *Ziziphus Spina-Christi* leaves

S/N	Phytochemical constituents	Composition of leaves mg/g <i>cashew</i>	Composition of leaves mg/g <i>ziziphus spina-christi</i>
1	Alkanoid	43.0	14.8
2	Flavonoid	47.8	53.9
3	Tannins	44.2	42.42
4	Saponin	23.6	8.66
5	Phenol	23.05	21.75

The analysis of cashew leaves revealed distinct phytochemical components, measured in milligrams per gram. Alkaloids were found at a concentration of 43.0 mg/g, flavonoids at 47.8 mg/g, tannins at 44.2 mg/g, saponins at 23.6 mg/g, and phenols at 23.05 mg/g. Similarly, the analysis of *Ziziphus spina-christi* leaves indicated alkaloids at 14.8 mg/g, flavonoids at 53.9 mg/g, tannins at 42.42 mg/g, saponins at

8.66 mg/g, and phenols at 21.75 mg/g. These findings align with previous research [11], demonstrating the consistency of compound concentrations within both plant species.

4 CONCLUSIONS

Extracts from the leaves of *Cashew and Ziziphus Spina-Christi* were successfully produced. The phytochemical analysis demonstrated that both *cashew and Ziziphus Spina-Christi* leaf extracts contain tannins (44.2) and (42.42), flavonoid (47.8) and (53.9) and other compounds are presents with potential corrosion inhibition properties, supporting the aim of investigating their suitability as corrosion inhibitors.

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