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DNA from Plant leaf Extracts: A Review for Emerging and Promising Novel Green Corrosion Inhibitors.

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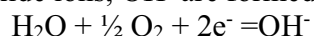
Abstract

With growing global awareness and concern for environmental protection through the use of less hazardous and environmentally-friendly extracts of plant origin, there has been a plethora of green corrosion inhibitors research with far reaching contributions to the science of corrosion prevention and control. Attention has increasingly turned towards green corrosion inhibitors, compounds of natural origin with anti-oxidant activity towards metals and their alloys. Green inhibitors have been investigated for their corrosion and adsorption properties with good results. The findings from these research works provide evidence of the adsorption behavior of green inhibitors which was confirmed by the adsorption isotherms that were proposed. Adsorption is the first step of any surface reaction and since corrosion is a surface phenomenon the effectiveness of green corrosion inhibitors is related to their ability to adsorb on metal surfaces. This review proposes the potential of plant dna as an emerging and promising novel inhibitor for mild steel. It begins with a list of plants that have been used in studies to determine corrosion inhibition properties and moves on to establish the adsorption behavior of bio macromolecules; protein, polysaccharides (chitosan) and dna. It reviews studies and investigation of dna interaction and adsorption on inorganic surfaces before focusing on the use of salmon (fish) sperm dna and calf thymus gland dna as green corrosion inhibitors for mild steel. It concludes that plant dna is a promising candidate for green corrosion inhibitor given the similarity between the plant and animal dna structure and function, and the fact that the use of plant is more environmentally sustainable than animal-based product.

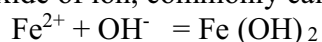
Keywords: Corrosion mechanism, Corrosion inhibitor, Green inhibitors, Bio-macromolecule, DNA, Adsorption.

1.0 Introduction

The American Society for testing and Materials defines corrosion as the chemical or electrochemical reaction between metals and their environment which results in the ruination of metals and their characteristics [1, 2]. This definition implies that corrosion has a deleterious effect on metals. Corrosion leads to an undesirable decline in quality of metals and their alloys. The best known case is of the rusting of iron. When a piece of iron is exposed to oxygen and moisture as in humid air, it is oxidized into iron (II) ions, Fe^{2+} (the corrosion reaction) and released from the anode while hydroxide ions, OH^- are formed at the cathode by reduction.



These ions combine to form a hydroxide of iron, commonly called rust.



The corrosion process requires four factors to occur. First is the anode, where metal dissolution takes place. Metal ions and electrons are released by oxidation and the electrons travel through an external conductor, a metallic path, to a cathode in close proximity to the anode, where they are consumed by positively charged ions in a reduction process. The metal ions from the anode travels through an ionic current path to the cathode. In addition to these four; anode, cathode, metallic external conductor and ionic current path, are associated fluid dynamics i.e. high water velocities which exposes fresh metal surface to water by sweeping away protective films, low pH (high concentration of free H^+ ion), this increases the release of electrons, high water temperatures, concentration of dissolved oxygen, and the presence of dissolved salts, which brings about the increased water conductivity [3]. Corrosion can be classified into different types on the basis of mechanism and media or environment of occurrence. Table 1 gives a brief description of types of corrosion according mechanism.

Table 1: Description of corrosion and their mechanisms [4]

Corrosion type	Description
<i>Uniform corrosion</i>	The disintegration of metals at the anode is evenly dispersed over the whole metal surface, making the surface thin. Thickness reduction is relatively uniform because the microscopic anode and cathode areas are frequently alternating.
<i>Pitting corrosion</i>	Pits are initiated by adsorption of impurities such as aggressive anions from the process streams which penetrate through passive films at irregularities. Aggressive anions such as halides and sulfates migrate through local breakdown of corrosion product films facilitating the process of pitting formation.
<i>Galvanic corrosion</i>	Occurs when two dissimilar metals; such as a more noble metal and a less noble metal, having different values of electrode potential or with different tendencies to corrode and in contact with electrolyte are connected.
<i>Crevice corrosion</i>	Crevice corrosion is a localized corrosion concentrated at crevices and introduced through the alterations in localized chemistry amidst the crevice
<i>Stress corrosion cracking</i>	Stress corrosion occurs as a result of the formation of cracks owing to the associated exertion of static tensile strength and chemical attack or corrosion.
<i>Fretting corrosion</i>	This is a form of erosion corrosion that takes place at the boundary where two mating compactly fitting surfaces are subjected to recurrent small virtual motion of small amplitudes of vibrations.
<i>Intergranular corrosion</i>	Refers to preferential corrosion or localized attack near or along metal grain or crystal boundaries in a corrosive media.
<i>Erosion corrosion</i>	Erosion corrosion is the flow-enhanced or assisted corrosion or impingement attack which occurs when a corrosive fluid moves relative to a metal immersed in it.
<i>Cavitation corrosion</i>	Localized corrosion which occurs in a rapidly moving liquid, causing large pressure variations.

Corrosion is the continuing dilapidation of materials such as metals, by chemical reaction with their environment. Even corrosion resistant alloys and stainless steels could turn out to be deteriorated or oxidized in corrosive environments. However, in natural environment, oxygen is the main cause of even corrosion of steels, metals and alloys. Furthermore, in acidic

environments, i.e., pH less than 7, the cathodic process is primarily the reduction of hydrogen ions. In addition, for corrosion in an alkaline or neutral environment, i.e., pH equals to 7 or pH greater than 7, reduction of dissolved oxygen is the major cathodic process that results to even corrosion. Hence, corrosion cannot be defined without reference to the environment. The environment of occurrence is therefore another basis for corrosion type's categorization. Table 2 gives the types of corrosive environment and their description.

Table 2: Types of corrosive environment and their description

Types of corrosive environment	Description
Atmospheric corrosion	Air and its pollutants can degrade material exposed to it. The electrolytes in atmospheric corrosion could be rain, dew, humidity or snow. [5]
Corrosion in seawater	Seawater is an electrolyte with a high concentration of natural salts. Metallic vessels and structure corrode when immersed in seawater. ⁵
Cooling water systems	Heat transfer fluids used in heat exchanger bundles such as water and water/glycol systems cause scales to be formed on the heat transfer surfaces [5].
Corrosion in soils	Soil corrosion affects metal and concrete structures that are buried in the ground as result of several variables in soil characteristics and properties [5].
Corrosion in concrete	Concrete reinforcements can degrade or rust when the mixing water reacts with the reinforcement steel [5].
Corrosion in petroleum industry	Petroleum exploration and production equipment such as pipeline, offshore installation are constantly subjected to corrosive chemicals and solutions during the lifetime of such facilities [5].

1.1 Economic implication of corrosion

Corrosion is the metal/environment interaction that leads to the deterioration of the metal and contamination of the environment. It has major engineering and economic impact such as structural failure and cost of repair, replacement and loss of product. C. C Technologies Inc., USA [6] in conjunction with Federal Highway Agencies, USA [7] and National Association of Corrosion Engineers [8] carried out a study to determine the impact of corrosion to the national economy. The study showed approximately 3.1% of the national gross domestic product of the USA in 2000, about 276 billion dollars, as the direct cost of corrosion. This revealed a staggering increase from the 82 billion US dollars estimated in 1975 by Battelle Columbus Laboratories and the National Institute of Standards and Technology. Uhlig (1985) [9] estimates the cost of corrosion to be 4-5% of the Gross national product of the United Kingdom, UK. Also about 5258 trillion Japanese Yen is said to be the estimated cost of corrosion in Japan. In general, for most industrialized nations, an average of about 3-4% of the GNP is lost to corrosion and to corrosion related damages [5]. Apart from the monetary cost of corrosion, several factors have led to the intense interest in the area of corrosion. Among these are (1) the dwindling material resources of the earth. (2) The application of the knowledge of engineering design in building our 21st century civilization vehicles such as airplanes, ships and cars would not be complete without the incorporation of the corrosion behavior of the metals used. (3) Corrosion has been stated a factor in some engineering disaster that have occurred in recent times. Some of these include oil pipeline explosions, drilling platforms failures and collapse of bridges. (4) There has been an

increase in the use of surgical implants for the repair and replacement of human body parts. These implants must be able to resist corrosion by very corrosive human blood or bio macro molecules such as proteins.

2.0 Corrosion Prevention / Control by Inhibition.

Corrosion process involves the oxidation of most metals and alloys and so corrosion can be stopped if oxidation can be stopped [5]. Generally, metals can be protected from corrosion by anodic and cathodic protection, anti-corrosion paintings and the utilization of corrosion inhibitors. Corrosion inhibitors are substances that significantly inhibit or prevent the rate of corrosion of metals exposed to a corrosive environment when added in small amounts. The utilization of corrosion inhibitors holds a significant place in corrosion prevention as it is always the first line of action against corrosion in the oil industry, for instance. They are however limited in application as they are not useful against localized corrosion even though effective in reducing uniform corrosion [10]. Corrosion inhibitors minimize the corrosion process by either increasing the anodic or cathodic polarization behavior (Tafel slopes), minimizing the migration of ions to the metallic surface or increasing the electrical resistance of the metallic surface [11]. They can be categorized according to

- Chemical nature as either inorganic or organic and
- Action mechanism as anodic- reduce metal dissolution rates, e.g. nitrite (NO_2^{2-}), chromate (CrO_4^{2-}), orthophosphate (PO_4^{3-}) and molybdate (MoO_4^{2-}), they are called passivating inhibitors; cathodic-hinders oxygen reduction or hydrogen evolution; mixed/adsorption- forming protective film on the metal surface by being chemically adsorbed, chemisorption [11].

Several research works have demonstrated and established the use of organic compound as good corrosion inhibitors of mild steel [12], [13], [14], [15], [16], and [17]. Inhibitors adsorb as film over metal surfaces acting as barrier layer between the metal and the corrosive environment. Although these barriers may affect only the anodic or cathodic areas, they usually cover the entire surface of the metal. The adsorbed organic adsorption inhibitors replace the adsorbed water molecule on the metal surface. This is called hydrophobicity. This action prevents the water from solvating metal ions, in this way controlling anodic reaction, or adsorption of H^+ ions and subsequent reduction of $\text{H}_2(\text{g})$ at the cathodic sites. There are two features which can lead to the increase inhibition efficiency by organic inhibitors. (1) Most well-known organic inhibitors contain electronegative functional groups and π electrons in conjugated double or triple bonds. Electrons are supplied through the π orbital. (2) The functional groups containing heteroatoms, nitrogen, sulfur and oxygen having free lone pair of electron have specific interactions with the metal surface, aiding inhibition [4]. The inhibitive effects of some synthetic organic compound containing multiple bonds and heteroatoms on mild steel corrosion have been established, although their toxic nature and cost have paved the way for research in more environment-friendly inhibitors [18], [19], [20] and [21].

3.0 Overview of Green Corrosion Inhibitors for Mild Steel

Mild or low carbon or plain carbon steel contains 0.05-0.25% carbon, approximately. This gives it metal properties such as malleability and ductility that are suitable for many engineering applications. They are also tough and strong making it useful for minimizing deflection in applications involving large cross-sections. It is relatively cheap and is now the most commonly used steel [18]. Mild steel, however, is highly liable to corrosion in both urban and marine environments.

Chromates remain, by far, the most efficient corrosion inhibitor for steel [2]. However due to high mobility of aqueous chromate (VI) ion in biological systems and higher reactivity with biochemical oxidation mediators, it is highly toxic, carcinogenic and usually known to be a highly hazardous soil and ground water contaminant [22]. This has necessitated a ban due to the increasing focus on sustainable industrial and environmental developments. Increasingly, attention has turned towards natural compounds with anti-oxidant activity towards metal and their alloys such as plant and animal extracts like garlic [23][24][25][26][27].

A lot of investigations have been carried out in the area of green corrosion inhibition for mild steel in acidic, basic and saline environments and sea water. This section highlights these investigations. Plants and plant products extracts such as aloe vera [27][28], ginger [29], Olives [30] bitter leaf [31], Mentha pulegium or pudding grass[32], Jathropa stem [33], cashew [34], mango, orange, passion fruits and cashew peels [35], Hibiscus sabdariffa[36], thyme, coriander, hibiscus, anis, black cumin, and garden cress [37], Eucalyptus, Hibiscus and Agaricus[38], curry[39][40], Indian Goosebery[41], Amaranthus[42], Carica papaya-pawpaw[43], Castor oil plant[44][45], Brassica campeteris-Field mustard[46] sweet sop[47] bush apple[48] butter fruit[49] white kopsia[50] neem[51] false daisy[52] and potato[53] have been investigated for their corrosion and adsorption properties with good results. The experiments were carried out in acidic [39] [40] [53] alkaline [54] [55] [56] and neutral mediums [57] [58] [59] to simulate corrosion processes in urban, industrial and marine environments. The active inhibitors present in these plants and plant products include allyl propyl disulfide from garlic, primary and secondary amines unsaturated fatty acids and bioflavonoids in garcinia kola seeds, lawsonia extract contains 2-hydroxy-1,4-naphthoquinone resin and tannin and coumarin, gallic acid and sterols. Other active ingredients include alkaloid berberine, pyrrolidine, alkaloid ricinine, ascorbic acids, amino acids, flavonoids pigments and carotene. Findings from these research indicate adsorption behavior of the ingredients as indicated by the adsorption isotherms proposed. The adsorption isotherms were confirmed by calculating thermodynamic parameters such as change in free energy, enthalpy and entropy. The isotherms include Langmuir, freundlich, Temkin, Frunkim.

4.0 Adsorption as Green Corrosion Inhibitors Mechanism

It has been proven that the inhibiting action of green (organic) inhibitors is attributed to interaction with metallic surface by adsorption[60]. Organic molecules are adsorbed at the metal-solution interface and form stable bonds; hence, reducing this corrosion rate. As surface adsorption rate progresses the amount of surface sites available for corrosion are lowered, resulting in decreasing corrosion rate. This is the reason most green-inhibitors are called adsorption inhibitors [60]. Adsorption is influenced by metal surface charge, electrolyte and inhibitor type. Adsorption is a process whereby molecules, atoms, ions or large particles concentrate, or accumulate, attach and adhere to metal surfaces. In this process surface penetration does not occur. Adsorption occurs in two different processes: physical adsorption and chemisorption. In the physical adsorption process, the electrically charged regions on the metal surface and the dipoles (organic ions) are held together by electrostatic forces. Covalent bonds also play a minute role in this attraction. In the adsorption process, the adsorbed molecule and the metal are involved in electron sharing. For all adsorption, the specie that adsorbs usually has a dipole in the molecule. For sulfoxides, sulfides and mercaptans the dipole in the molecule is sulfur atom (negatively charged). For aliphatic, aromatic or heterocyclic amines; the dipole is nitrogen (positively charged); oxygen (negatively charged) for aldehydes and ketones and double

or triple carbon bond (negatively charged) for hydrocarbons. Organic adsorption inhibition proceeds through several different mechanisms.

1. To decrease reactant diffusion a physical barrier is formed by the inhibitor.
2. Metal reactivity is reduced by the adsorption of the inhibitor on active sites
3. The electrode reactions are influenced by changes in the surface potential brought about by the inhibitor.
4. The inhibitor may play a part in the electrode reaction and form a stable complex on the metal surface.

To further buttress the fact of adsorption as the mechanism for green inhibitors, most of the studies investigated the adsorption isotherm that describe the adsorption behavior of the various inhibitors; Langmuir, Freundlich, Tempkin, Frumkin and Flory-Higgins [61]. Adsorption isotherm is the amount of adsorbate on the adsorbent as a mathematical function, some purely empirical others semi-empirical with a kinetic basis, of liquid concentration or gaseous pressure at a constant temperature.

5.0 Adsorption in Bio macro molecules: Proteins, Polysaccharides and DNA

Large biomolecules such as protein can be adsorbed on metal surfaces [62] [63]. The major driving force for this are surface energy, intermolecular forces, hydrophobicity and electrostatic interaction. This knowledge can be utilized in selection for optimal performance in both engineering and biomedical applications. Proteins are adsorbed to metal surfaces to reduce higher surface energy caused by the surface termination of the normal crystalline repeating subunits of metals. Bio molecular Adsorption Database, BAD [64] is a free online resource with experimental protein absorption data [65].

Another bio macro molecule that has shown not just good adsorption behavior but also corrosion inhibition properties is chitosan. Chitosan is a natural polymer, a linear polycation polysaccharide biopolymer, extracted by the deacetylation of chitin from the shells of crustaceans, such as crabs, shrimps and snails in sea food waste [66]. Chitosan is produced in large quantities annually and in low cost. Due to its non-toxicity, and anti-corrosive behavior ascribed to the presence of amino and hydroxyl groups it has been investigated for its corrosion inhibition potential. Gupta *et al*, 2018[66] employing gravimetric, electrochemical and surface analysis found that chitosan exhibited an inhibition efficiency of 73.8% alone and 90% in combination with potassium iodide KI. The investigation was carried out on mild steel in 1M sulfamic acid medium. The formation of inhibitor film on the metal surface followed the Langmuir isotherm. This was corroborated for the by calculation of kinetic and thermodynamic parameters [67].

DNA, or deoxyribonucleic acid is another bio macro molecule. DNA consists of subunits called nucleotides linked to each other forming 2 polynucleotides strands. Nucleotides are like the letters that make up the words in genetic language. Each of these nucleotide has a five-carbon sugar (deoxyribose), phosphate and a nitrogen-containing nucleobase part. The nucleobases are Adenine (A), Guanine (G), Thymine (T) and Cytosine(C). The polynucleotide strands are formed by the covalent bonding of the sugar of one nucleotide to the phosphate of another nucleotide. The nitrogenous rings of two separate polynucleotide strands bond into base pairs, A always with T and C always with G, and align linearly to connect two sugar-phosphate backbones, which align perpendicularly to form a ladder-like structure. The base pair bond is a hydrogen bond. DNA is the hereditary or genetic material that carries or stores biological information for the development and function of living things. DNA is present in both plant and animal cells, having

the same structure and function. Like the other bio macro molecule, proteins and chitosan, DNA has also been shown to adsorb on inorganic solid surfaces.

6.0 DNA adsorption and its implication for corrosion inhibition

To understand DNA adsorption we first have to interpret the various intermolecular forces in play. These forces result from the physiochemical properties of DNA bases. The intermolecular forces are;

- 1) Charge: The number of negative charges on a chemically synthesized n-mer DNA is related to the number of monomers it contains. There are therefore n-1 negative charges on and n-mer DNA from the backbone phosphate of a chemically synthesized n-mer DNA.
- 2) Hydrophobicity: Hydrophobicity is often ranked by the empirically calculated Log P_(o/w) value. The octanol/water partition coefficient, P is defined as the coefficient for solvent partition between 1-octanol and water. $P = \text{concentration in octanol phase} / \text{concentration in aqueous phase}$. $\text{Log } P_{(o/w)} = \text{Log } 10 (\text{partition coefficient})$. The Log P values for thymine, cytosine, adenine and guanine are -0.6+/-0.04, -1.73+/-0.39, -0.14+/-0.03 and -0.94+/-0.04 respectively (Guckian *et al*, 2000) [68]. The negative value of log P indicates strong hydrophilicity. Deoxyribose has a log P value of -2.32 making bases more hydrophobic in comparison to the sugar ring and phosphate backbone.
- 3) Sizes: To calculate the maximum adsorption capacity of DNA the sizes of the nucleobases are crucial. This is applicable if DNA is adsorbed parallel to the surface. The surface area of the bases in nm² are 1.42, for thymine and adenine, 1.27 for cytosine and 1.54 for guanine in accord with the approx. 2nm diameter of a DNA duplex[68].
- 4) Bonding: Nucleobases are responsible for DNA-metal bonding. The nitrogen and exocyclic keto groups in the base ring are capable of bonding with metal ions but the exocyclic amino groups do not [69], [70].

DNA adsorption is required in DNA microarray optimization, biosensor development and nanoparticle functionalization. This has necessitated increased and intense research interest in the interaction between DNA and inorganic surfaces. Zhao and Johnson, 2007[71] reported the molecular dynamics simulation of the adsorption of DNA segment with 12 base pairs on a (8, 8) single walled carbon nanotube (SWNT) in water. The simulation showed that the hydrophobic end groups of the DNA are attracted to the hydrophobic SWNT surface of uncharged SWNT, a clear indication that DNA binds to the external surface of an uncharged or positively charged SWNT. Liu and Liu, 2015[72] also investigated DNA adsorption by Indium Tin Oxide (ITO) Nanoparticles. The work looked into the interaction of ITO with fluorescently labeled single stranded-oligonucleotides in order to understand its bio interface chemistry and application as biosensors. The results showed that the fluorescently labelled DNA was quenched by adsorption on the ITO. The surface charge of the ITO strongly influenced the DNA-ITO interaction. It also confirmed that DNA adsorption was largely dependent on phosphate backbone. Liu *et al*, 2011[73] studied the DNA adsorption mechanism with mesoporous silica Nano particle in aqueous solution. Carlson *et al*, 2014[74] studied small-scale isolation of genomic DNA via adsorption onto calcium aluminate and silicate glass surfaces. Also Bachir Saoudi *et al*, 2000[75] devoted efforts to study the kinetics and thermodynamics of DNA adsorption on polypyrrole, a conducting polymer, showing a decrease in dielectric parameters, an effect of DNA adsorption. Some DNA types such as thiolated DNA can interact with gold surfaces through DNA bases while studies of non-thiolated DNA adsorption as a function of salt, pH, temperature and DNA structures have been submitted [76].

It is plausible to presume that knowledge gained from the various DNA adsorption research interest highlighted above may not be directly applicable to DNA adsorption and its influence on corrosion inhibition in metals in general and mild steel in particular. The following reasons may be adduced; 1) DNA adsorption is a function of size of the adsorbing surface 2) DNA may interact differently and 3) the effect of salt concentration, pH of medium and temperature could be markedly different [76]. However there are results to the contrary. Already fish DNA adsorption and corrosion inhibition on mild steel has been investigated. Hu *et al.* (2017) [77], investigated the influence of bio-macromolecule DNA corrosion inhibitor on mild steel. A novel inhibitor, salmon sperm DNA, obtained from China and prepared to a concentration range from 5mg/L to 20mg/L was used to protect API 5L X80 steel corrosion in 1M HCl solution. To investigate the inhibition performance of the salmon sperm DNA, weight loss measurements were carried out in the presence and absence of the DNA showing significant decrease in corrosion rate as the concentration of DNA increase reaching an inhibition efficiency of 91.6%. The adsorption of the salmon sperm DNA on x80 steel was explained using electrochemical studies. It showed that the open circuit potential OCP values increased from -499mV in the absence of DNA to -452mV, a shift towards a more positive potential in the presence of the DNA inhibitor[77]. The chemical composition of the inhibited surface was also investigated using x-ray photoelectron spectroscopy, XPS. There was a difference between the binding energies of C 1s, O 1s, N 1s, P 2p Fe 2p in the pure DNA and sample of powder from inhibited surface. For instance the interaction between N and Fe, creating an N-Fe bond, generated a 0.64 eV increase from 398.8 eV (pure DNA) to 399.4(sample powder). This result demonstrated that DNA can adsorb to metals by its polar group which contain N atoms. Hu *et al.* 2017 [77], using scanning electron microscope SEM the surface morphology of the X80 steel sheets in 1M HCl in the presence and absence of the salmon sperm DNA. While the steel surface without the salmon sperm DNA showed rough and non-uniform morphology, there were barely recognizable signs of corrosion on the steel with the salmon sperm DNA inhibitor. An adsorption model presented to further elaborate the inhibition mechanism of the salmon sperm DNA showed DNA molecule adsorbed to the surface of the metal, dispelling the water molecules, hydrogen and chloride ions which covered the metal surface before the application of DNA. The conclusion drawn from the foregoing is that bio macromolecule DNA from salmon sperm has worked as a novel green corrosion inhibitor on X80 steel in 1M HCl. Agboola, *et al.*, (2018) [78] in their ground breaking work on the adsorptive performance mechanism of the DNA calf thymus gland (CTG_{DNA}) on 3CR12 stainless steel as a corrosion inhibitor in acidic medium showed that DNA is a promising and eco-friendly inhibitor. Working with 1-2.5 M HCl, the corrosion of the steel was studied at different temperature and inhibitor concentration, obtaining the maximum inhibition efficiency of 75.79% at 10⁰C and 20 mg/L. The evaluation included Tafel polarisation plots, which showed that DNA is mixed type inhibitor and X-ray powder diffraction analysis which confirmed an adsorptive mechanism that was proposed [78].

7.0 Conclusion

At the chemical level, plant and animal DNA have the same shape and their molecules are made from the same four nucleotides. The only difference is the arrangement of the four nucleotides in DNA. According to research, plant and animals may produce some proteins in common such as cytochrome. Also, from the environmental and sustainability sciences standpoint it is more beneficial to use plant product DNA than animal product DNA. This is because animal-based products are more resource intensive than plant based replacements. Shepon *et al.* (2018)[79]

showed that for eggs, poultry, beef, dairy and pork, plant-based replacements can yield as much as 2 to 20-fold more products for every unit of cultivated cropland. This means the use of animal products have more potential hazards to the environment than plant products. Furthermore Tilman and Clark (2014) [80]; Springman *et al* (2016) [81]; Eshel *et al* (2014) [82]; Nijdam *et al* (2012) [83] and Aleksandrowicz *et al* (2012) [84] established that the share of animal-based cost to the environmental cost in the food production systems in present times is disproportionate. The conclusion, here drawn is that plant DNA fulfil the basic requirements of function and environmental sustainability for consideration as efficient green corrosion inhibitors and this is a potential direction for the future of corrosion inhibitors. Through improved understanding of DNA surface reactions we can envision related application and developments which can lead to preparation of new materials. It is on this basis that this proposal is being made for the use of plant DNA as a corrosion inhibitor for mild steel. Ongoing research work with ginger leave extract DNA as a corrosion inhibitor is showing good prospects.

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