Inhibition of Bio-corrosion of Mild Steel in Five Food Paste Media Treated with Onion (*Allium cepa* L.) Extracts

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Abstract

Reduction or control of microbial colonisation of metal surfaces leading to corrosion is a challenge to food and pharmaceutical companies. Scientists are searching for suitable green solutions. This study investigates the inhibition of microbial activity on the surfaces of mild steels in food paste environments using onion (Allium cepa L.) extracts. Five different food pastes prepared from tomato (Lycopersicon esculentum Mill.), groundnut (Arachis hypogaea L.), melon (Citrullus vulgaris Schrad.), cassava (Manihot esculenta Crantz.) and cowpea (Vigna unguiculata L. Walp.) were used. The mild steels were prepared as chips with dimensions, of (2 x 1 x 0.08 cm), degreased, surface sterilized and preserved in a desiccator. Each prepared food paste was dispensed into five bowls with onion extracts applied at 0g, 5g, 10g, 15g, and 20g to the respective food bowls. Five mild steel chips were then immersed in each bowl to initiate corrosion for thirty five days. At room temperature and keeping other conditions the Bacterial population, weight loss, corrosion rate and inhibition efficiency were estimated. Total viable bacterial counts obtained for the five food pastes with inhibitor ranged from $1.9x10^2 – 3.2x10^3$ cfu/g, while for food pastes without inhibitor ranged from $4.1x10^3$ – $9.9x10^3$ cfu/g. Microorganisms isolated were Pseudomonas sp, Streptococcus sp, Micrococcus sp, Bacillus sp, Corynebacterium sp., Serratia sp., Klebsiella sp. and Alcaligenes sp. Higher weight losses were recorded for mild steel coupons inserted in food pastes without inhibitor. Onion extracts serve as effective bio-corrosion inhibitor by reducing the corrosion rate of mild steel coupons immersed in food paste environments over time. Estimates of inhibition efficiency increased as higher weights of extracts were applied to food paste environments. Application of onion extracts suggests an alternative to the use of synthetic corrosion inhibitors which are not renewable, environmentally and ecologically friendly.

Keywords: Viable count reduction, Weight loss, Inhibition efficiency, Decreased corrosion rate

Inhibition de la Bio-Corrosion de L'acier Doux dans Cinq Milieux de Pate Alimentaire Traites avec des Extraits d'Oignon (*Allium Cepa* L.)

Resume

La réduction ou le contrôle de la colonisation microbienne des surfaces métalliques conduisant à la corrosion est un défi pour les sociétés alimentaires et pharmaceutiques. Les scientifiques recherchent des solutions vertes appropriées. Cette étude examine l'inhibition de l'activité microbienne sur les surfaces des aciers légers dans les environnements de pâte alimentaire à l'aide d'extraits d'oignon (Allium cepa L.). Cinq pâtes alimentaires différentes préparées à partir de la tomate (Lycopersicon esculentum Mill.), L'arachide (Arachis hypogaea L.), le melon (Citrullus vulgaris Schrad.), le manioc (Manihot esculenta crantz.) Et le dolique (Vigna unguiculata L. Walp.) Ont été utilisés. Les aciers légers ont été préparés sous forme de puces avec des dimensions, de (2 x 1 x 0,08 cm), dégraissées, stérilisées en surface et conservées dans un dessiccateur. Chaque pâte de nourriture préparée a été distribuée dans cinq bols avec des extraits d'oignon appliqués à 0g, 5g, 10g, 15g et 20g dans les bols alimentaires respectifs. Cinq copeaux en acier doux ont ensuite été immergés dans chaque bol pour *initier la corrosion pendant trente-cinq jours. À température ambiante et en maintenant d'autres conditions, la population bactérienne, la perte de poids, le taux de corrosion et l'efficacité d'inhibition ont été estimées. Les dénombrements bactériens viables totaux obtenus pour les cinq pâtes alimentaires avec un inhibiteur variaient de 1,9x102 - 3,2x103 cfu / g, tandis que pour les pâtes alimentaires sans inhibiteur variaient de 4,1x103 _ 9,9x103 cfu / g. Les micro-organismes isolés étaient Pseudomonas sp, Streptococcus sp, Micrococcus sp, Bacillus sp, Corynebacterium sp., Serratia sp., Klebsiella sp. et Alcaligenes sp. Des pertes de poids plus élevées ont été enregistrées pour les coupons en acier doux insérés dans les pâtes alimentaires sans inhibiteur. Les extraits d'oignons servent d'inhibiteur de bio-corrosion efficace en réduisant le taux de corrosion des coupons en acier doux immergés dans des environnements de pâte alimentaire au fil du temps. Les estimations de l'efficacité d'inhibition ont augmenté à mesure que des poids plus élevés des extraits ont été appliqués aux environnements de pâte alimentaire. L'application d'extraits d'oignon suggère une alternative à l'utilisation d'inhibiteurs de corrosion synthétique qui ne sont pas renouvelables, respectueux de l'environnement et écologiquement amicaux.*

Mots-clés: réduction du nombre viable, perte de poids, efficacité de l'inhibition, diminution du taux de corrosi

تثبيط التآكل الحيوي للصلب الطري في خمسة أوساط معجون طعام معالجة بمستخلصات البصل (Allium cepa L.)

نبذة مختصرة

يمثل الحد من الاستعمار الميكروبي للأسطح المعدنية المؤدية إلى التآكل أو التحكم فيه تحديًا لشركات الأغذية والأدوية. يبحث العلماء عن حلول صديقة للبيئة مناسبة. تبحث هذه الدراسة في تثبيط النشاط الجرثومي على أسطح الفولاذ الخفيف في بيئات معجون الطعام باستخدام مستخلص البصل (Allium cepa L.). تم استخدام خمسة معاجين غذائية مختلفة محضرة من الطماطم (Lycopersicon esculentum Mill.) والفول السوداني (Arachis hypogaea L.) والبطيخ (Citrullus vulgaris Schrad.) والكسافا (Manihot esculenta Crantz.) واللوبيا (Vigna unguiculata L. Walp.). تم تحضير الفولاذ الخفيف على شكل شرائح بأبعاد (2 × 1 × 0.08 سم) ، منزوعة الشحوم ، معقم سطحها وحفظها في مجفف. تم توزيع كل معجون غذائي محضر في خمسة أوعية مع مستخلصات البصل المطبقة عند 0 جم ، 5 جم ، 10 جم ، 15 جم ، و 20 جم في أوعية الطعام المعنية. تم بعد ذلك غمر خمس شرائح فولاذية معتدلة في كل وعاء لبدء التآكل لمدة خمسة وثلاثين يومًا. في درجة حرارة الغرفة والحفاظ على الظروف الأخرى تم تقدير عدد البكتيريا وفقدان الوزن ومعدل التآكل وكفاءة التثبيط. تراوحت الأعداد البكتيرية الحيوية التي تم الحصول عليها للمعاجين الغذائية الخمسة مع المانع من 1.9 x102 - 3.2x103 cfu / g، بينما تراوحت معاجين الطعام بدون مثبط من 4.1 x103 _ 9.9x103 cfu / g. الكائنات الحية الدقيقة المعزولة هي Pseudomonas sp ،Streptococcus sp ،Micrococcus sp ، Bacillus sp ،Corynebacterium sp. ،Serratia sp. ،Klebsiella sp. وAlcaligenes sp. تم تسجيل فقد أعلى في الوزن لكوبونات الفولاذ الطري التي تم إدخالها في معاجين الطعام بدون مثبط. تعمل مستخلصات البصل كمثبط فعال للتآكل الحيوي عن طريق تقليل معدل التآكل لقسائم الفولاذ الطري المغمورة في بيئات معجون الطعام بمرور الوقت. زادت تقديرات كفاءة التثبيط مع تطبيق أوزان أعلى للمستخلصات على بيئات معجون الطعام. يقترح تطبيق مستخلصات البصل بديلًا لاستخدام مثبطات التآكل الاصطناعية ث هي ليست متجددة وصديقة للبيئة وصديقة للبيئة.

الكلمات المفتاحية: تقليل العدد القابل للتطبيق ، فقدان الوزن ، كفاءة التثبيط ، معدل التآكل المنخفض

Introduction

The deterioration of metal or other materials due to chemical, mechanical and biological action in an environment is described as corrosion. Corrosion initiated by biological agent is called bio-corrosion. Contact and gradual colonisation of metal surfaces by microorganisms cause severe changes in ion concentrations, conductivity, pH and dissolved oxygen, altering the passive and active behaviour of the metallic substratum and its corrosion products (Amadi *et al*., 2010, Salami *et al*., 2015). Critical factors during corrosion are moisture content of the environment and duration of exposure of substratum, influence the rates of corrosion observed in the exposed substratum. Corrosion reactions are electrochemical in nature and involve anodic and cathodic reactions (Oparaodu and Okpokwasili, 2014). Bio-corrosion is the result of electrochemical reactions that are driven or influenced by microorganisms, which are present as biofilm (Kip and van Veen, 2015). Zuo (2007) stated that microbes do not only cause corrosion, but can also inhibit or protect against corrosion, described as Microbiologically Influenced Corrosion (MIC) and microbiologically influenced corrosion inhibition (MICI). The anode is the part of the metal surface that corrodes and dissolves in the electrolyte. The portion of the metal surface that does not dissolve is the cathode. It is the site where chemical reactions absorb the electrons generated at the anode. During metal corrosion, either ions or electrons are released from the metal. Chemicals like acids cause corrosion by stimulating anodic reactions. By consuming hydrogen, microbes stimulate cathodic reactions and also through secretion of enzymes and acidic metabolites (Kip and van Veen, 2015). Most damaging corrosion takes place in the presence of a multispecies biofilm because the interactions between the different species induce a cascade of biochemical reactions in the oxic and anoxic parts of the biofilm that act synergistically to exacerbate corrosion (Zuo, 2007). Corrosion is a global problem that affects a large variety of industries and municipal services. Microbial corrosion of metals in constructed facilities is one of the difficult problems facing food and pharmaceutical industries; Microbial corrosion increases the cost of equipment maintenance, risk of equipment failure and likely loss of production time (Ovri *et al*, 2013). Other issues of concern, is the contamination of products by corroded materials during food processing which may result in food poisoning. In order to afford cost of equipment, local food processing industries fabricate equipment using materials like tinned copper in place of the specified stainless steel recommended for use (Fontana, 1987). The concern for suitability of any material used for fabrication, especially when it is meant for specific environments, is not reflected in the choice. For some years in Nigeria now, there has been an increase in the local fabrication of food processing equipment using other materials in place of stainless steel (Ofoegbu *et al*, 2011). On the part of fabricators, the acceptance of this equipment by the food processing outfits and rural small scale farmers is a boost to their business. The fabricators make use of a variety of metallic materials ranging from mild steels (coated and uncoated), galvanized steel to different grades of stainless steel. Following the challenge of material corrosion, the application of corrosion inhibitor is inevitable. The use of plants extracts or organics as inhibitors is becoming the subject of extensive investigation (Abiola *et al*, 2007). It is also fast replacing the synthetic and expensive hazardous organic inhibitors (Umoren *et al*, 2008). They are environmentally and ecologically friendly. Plant extracts constitute several organic compounds which have corrosion inhibiting abilities. These extracts of plants as well as the corrosion inhibition abilities vary widely depending on the part of the plant used (Chalchat *et al*, 1993; Eddy *et al*, 2009). The extracts can be obtained from the leaves, seeds, heart wood, bark, roots and fruits of plants to inhibit metallic corrosion (Zucchi and Omar, 1985; Okafor *et al*, 2005; Bendahou *et al*, 2006; Okafor *et al*, 2008). Extracts from plants play this role by inhibiting the activities of microorganisms inducing corrosion. Onion from recent reports is an effective inhibitor and it is available. The extracts of onion contain *allylpropyl disulphide* and *quercetin* which can act as a good corrosion inhibitor (Mahmoud, 2006). The onion extracts absorb water molecules on the surface of the metal thereby forming a barrier between the metal and the species involved in the corrosion process; this makes it effective in inhibition. Onion extract is a mixture of various compounds containing carbon (C), oxygen, and nitrogen atoms, and all can be adsorbed on the corroded metal. Koch *et al.* (1996) and Okafor *et al*. (2006) reported the potential of onion extracts as suitable natural bio-corrosion inhibitor of mild steel in acid media. The extracts of *Allium cepa* decreases corrosion rate by shielding the surfaces of mild steels from bacterial species that promote corrosion. Okafor *et al*.(2014) stated that mild steel sheets are composed by weight (%) of Mn (0.64), P (0.06), C (0.19), S (0.05), Ni (0.09), Cr (0.08), Mo (0.02), Cu (0.27), Si (0.26) and the rest Fe. One simple and reliable but convenient method of measuring corrosion of metal and steel products is by weight loss analyses. The corrosion rate is determined as the loss of weight of the material as a function of time. Corrosion rate assists scientists to understand the vulnerability of metals to corrosion. The objective of this study was to evaluate onion extracts as bio-corrosion inhibition agent of mild steel in food pastes.

Materials and Methods

Five different food materials were bought from Edaiken market, Uselu, Benin City, Nigeria. They were tomato fruits (*Lycopersicon esculentum* Mill.), groundnut (*Arachis hypogaea* L.), melon (*Citrullus vulgaris* Schrad.)), cassava tubers (*Manihot esculenta* Crantz.) and black-eyed cowpea (*Vigna unguiculata* L. Walp.). Each food paste used in the study was prepared as follows: 1 kilogramme (Kg) of fresh food material was washed with distilled water and ground in a clean blender to a fine watery paste. For the cowpea, the paste was prepared by soaking 1kg of cowpea in lukewarm water for about ten minutes, washed off the transparent seed coat and then ground with a blender adding distilled water to obtain a watery paste. The prepared paste of each food material was equally distributed into five plastic bowls and labelled. (i.e., five plastic bowls for each food material).

Mild steel sheets were obtained and cut to form coupons. One hundred and twenty-five coupons cut into dimension of 2cm X 1cm X 0.08cm (height, breadth and thickness respectively). All cut edges were made smooth to give good blunt surfaces. The mild steel coupons were degreased by washing with ethanol, cleaned in acetone, dried and weighed with a digital balance to obtain the initial weight of the coupons and preserved in a desiccator.

The onion extract was prepared by peeling off the dry scale leaves, washed with distilled water, sliced with a sterilized knife and then ground to fine paste. The paste was filtered and pressed aseptically using a muslin cloth to get the extract. Different weight of extracts, 5g, 10g, 15g and 20g were weighed using a digital balance and each one was mixed with prepared food paste following the design of experiment. The five plastic bowls with food paste were mixed with 0g, 5g, 10g, 15g, and 20g of onion extract respectively. Five mild steel coupons were immersed in each plastic bowl of food paste containing a specific weight of onion extract. The mild steel coupons were retrieved using a pair of sterilised forceps every seven days interval, which alters the corrosion rate after it's removal every week for 5 weeks from the food paste, observed, washed in acetone, dried and weighed. At the end of five weeks, the mild steels were cleaned and dried to obtain the final weight, from which the total weight loss and the corrosion rate and inhibition efficiency were estimated. The interval retrieval of coupons was to ascertain what corrosion effect had taken place on the coupons at the end of each 7-day observation period and to compare the effect of time on rates of corrosion in the five food pastes under study. The weight of retrieved coupon after corrosion initiation was compared with initial weight, the difference indicating metal loss during the exposure period. The average weight loss and corrosion rate (CR) were calculated. Corrosion rate was calculated assuming uniform corrosion over the entire surface of the coupons. The corrosion rate in mils per year (mpy) of metal degraded was calculated from the weight loss using the formula:

$$CR = \frac{W}{(D \times A \times t)} \times K$$

where: W= weight loss in grammes; K = constant (22,300); D = metal density in g/cm^3 (i.e., mild steel = 7.85g/cm^3); A = coupon area; t = time (days)

Ferry *et al*. (2013) stated that inhibition efficiency (IE, %) could be defined based on corrosion rate values of the mild steel coupons used.

$$IE\ (\%) = \frac{CRo - CRi}{CRo}$$

Where IE = inhibition efficiency, expressed in percentage; CR_o = corrosion rate of control coupon; CR_i = corrosion rate of inhibited coupon

Ten-fold serial dilutions of each food sample was carried out using sterile pipettes to obtain 10^{-3} dilution. The ten-fold serial dilution was carried out by transferring one milliliter (1 ml) watery paste of each food sample into 9 ml sterile distilled water and mixed thoroughly to give 10^{-1} dilution. One milliliter (1ml) of the 10^{-1} dilution was aseptically transferred into another tube of 9 ml sterile distilled water to give 10 ml of 10^{-2} dilution. Repeating the above procedure, dilution of 10^{-3} was obtained. Thereafter, 0.1 ml of each 10^{-3} dilution was poured plated in nutrient agar (NA). The nutrient agar plates were incubated at 37 ^{O}C for 24-48 hours for the growth of bacterial isolates. The colonies that developed were counted. The total bacterial load was calculated by multiplying the colony count with dilution factor and expressed as colony forming units per gramme (cfu/g). After incubation, viable colonies were recorded as respective of the microbial in colony forming units per g. The isolation and identification of bacterial isolates were carried out according to the methods of Bergey's Manual of Determinative Bacteriology (Bucchanan and Gibbons, 1974). Antifungal agent (0.5 ml of griseofulvin solution per plate prepared by dissolving 300 mg of griseofulvin in 12.5 ml of sterile distilled water) was incorporated into NA to inhibit fungal growth.

Results and Discussion

Table 1: Total Viable Bacterial Counts in the Different Food Pastes Treated with Onion Extracts Determined After Thirty Five Days of Corrosion Induction

Type of food paste	Mean bacterial counts (cfu/g)	
	Without onion extracts	**With onion extracts**
Cowpea	$9.9 \times 10^3 \pm 0.1 \times 10^3$	$3.2 \times 10^3 \pm 0.01 \times 10^3$
Melon	$4.1 \times 10^3 \pm 0.01 \times 10^3$	$1.3 \times 10^3 \pm 0.01 \times 10^3$
Groundnut	$7.6 \times 10^3 \pm 0.02 \times 10^3$	$2.1 \times 10^3 \pm 0.01 \times 10^3$
Tomato	$7.3 \times 10^3 \pm 0.02 \times 10^3$	$1.9 \times 10^2 \pm 0.01 \times 10^2$
Cassava	$5.9 \times 10^3 \pm 0.02 \times 10^3$	$1.3 \times 10^3 \pm 0.1 \times 10^3$

Values = mean ±S.D

The total viable bacterial counts for the five food pastes treated with or without inhibitor (onion extracts) is shown in Table 1. The presence of onion extracts in the food paste reduced the bacterial counts. The total viable bacterial counts with inhibitor ranged from 1.9×10^2 - 3.2×10^3 cfu/g. While the total viable bacterial counts for the five food pastes without inhibitor ranged 4.1×10^3 - 9.9×10^3 cfu/g. The bacterial loads in the food pastes without inhibitor were higher than the bacterial loads in the food pastes with inhibitor. The least mean bacterial count was recorded in tomato paste.

Table 2 shows the occurrences of the bacterial isolates identified in the five food pastes either with or without onion extracts. It is clear that the isolates recorded in food pastes with or without inhibitor were not necessarily the same. Also, differences within each food paste were recorded. For example, four bacterial isolates – *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella* sp., and *Serratia* sp. were not recorded in the food pastes with inhibitor.

Table 2: Occurrence of the Bacteria Isolated from the Five Food Pastes with or without the Onion Extracts as Inhibitor

Bacterial isolates recorded	cowpea paste		Groundnut paste		Melon paste		Cassava paste		Tomato paste	
	+ inhibitor	- inhibitor	+ inhibitor	- inhibitor	+ inhibitor	- inhibitor	+ inhibitor	- inhibitor	+ inhibitor	- inhibitor
Bacillus sp.	+	+	+	+	+	+	+	+	+	-
Micrococcus sp	+	+	+	-	+	+	-	+	-	-
Streptococcus sp	+	-	+	-	-	-	+	-	-	-
Pseudomonas sp	+	-	-	+	+	+	-	+	+	+
Alcaligenes sp	-	-	-	-	-	-	+	-	-	-
Corynebacterium sp	+	-	+	-	-	-	+	-	-	-
Escherichia coli	-	-	-	-	-	-	-	-	-	+
Staphylococcus aureus	-	+	-	+	-	-	-	-	-	+
Klebsiella sp	-	+	-	+	-	-	-	-	-	+
Serratia sp	-	-	-	-	-	-	-	+	-	+

+ = present , - = absent

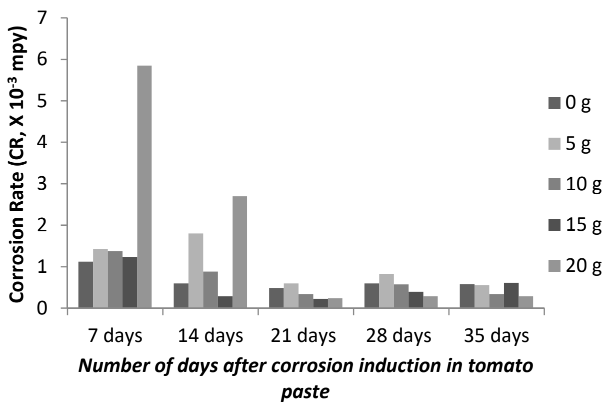
Table 3: Weight Loss of Corroded Mild Steel Coupons Inserted in Different Food Pastes Treated with Varying Quantities of Onion Extracts as Bio-Corrosion Inhibitor

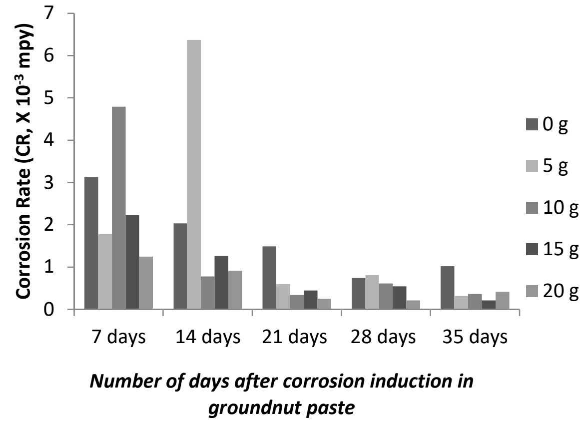
TYPE OF FOOD PASTE	APPLIED TREATMENT	7 DAYS	14 DAYS	21 DAYS	28 DAYS	35 DAYS
TOMATO	Without inhibitor	0.03	0.03	0.04	0.05	0.04
	5 g inhibitor	0.02	0.01	0.02	0.04	0.05
	10 g inhibitor	0.02	0.02	0.01	0.03	0.03
	15 g inhibitor	0.03	0.01	0.01	0.02	0.03
	20 g inhibitor	0.02	0.01	0.01	0.02	0.02
GROUNDNUT	Without inhibitor	0.04	0.06	0.06	0.04	0.07
	5 g inhibitor	0.03	0.02	0.03	0.04	0.03
	10 g inhibitor	0.03	0.02	0.02	0.03	0.03
	15 g inhibitor	0.02	0.03	0.02	0.03	0.02
	20 g inhibitor	0.02	0.03	0.01	0.01	0.02
MELON	Without inhibitor	0.05	0.04	0.05	0.05	0.15
	5 g inhibitor	0.04	0.04	0.05	0.05	0.06
	10 g inhibitor	0.03	0.03	0.04	0.04	0.05
	15 g inhibitor	0.02	0.01	0.02	0.03	0.03
	20 g inhibitor	0.01	0.02	0.02	0.02	0.03
CASSAVA	Without inhibitor	0.04	0.06	0.07	0.08	0.08
	5 g inhibitor	0.03	0.03	0.03	0.04	0.05
	10 g inhibitor	0.03	0.02	0.02	0.03	0.04
	15 g inhibitor	0.02	0.01	0.01	0.02	0.03
	20 g inhibitor	0.01	0.01	0.01	0.02	0.02
COWPEA	Without inhibitor	0.05	0.05	0.06	0.06	0.07
	5 g inhibitor	0.04	0.04	0.03	0.04	0.04
	10 g inhibitor	0.03	0.03	0.02	0.03	0.03
	15 g inhibitor	0.02	0.02	0.02	0.02	0.02
	20 g inhibitor	0.01	0.01	0.01	0.02	0.02

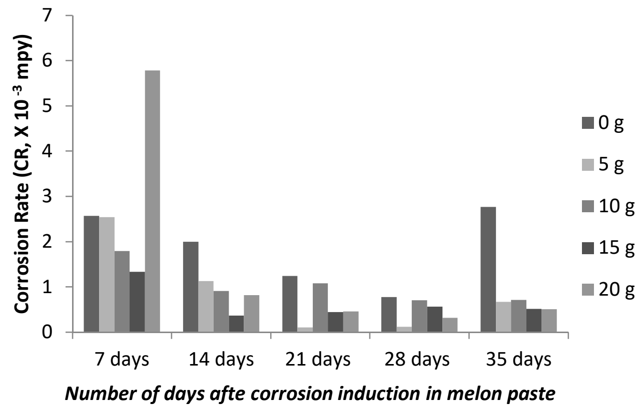
The results of the average weight loss of mild steel in the five food paste environment are shown Table 3. Higher weight losses were recorded for mild steel coupons inserted in food pastes without inhibitor. Weight loss increased over time. Generally, the least weight losses were observed in food pastes treated with 20 g onion extracts. The results of the average corrosion rate of mild steel coupons in the five food paste environments are shown in Figure 1(a-e). The inhibition efficiency of the different concentrations of onion extracts in the five food paste environments are shown in Figure 2 (a-e).

Increasing the weight of onion extracts decreased corrosion rates when compared to control over time. In cowpea paste environment, the least corrosion rates were recorded thirty five days after induction. In this food paste, the pattern of inhibition of corrosion was clearly dependent on weight of onion extracts applied (see Figure 1a). This was depicted by the inhibition efficiency estimated (Figure 2a). Some negative values were obtained as estimates of inhibition efficiency in tomato paste (Figure 2b). This suggests likely cessation of corrosion activity at such instances following the formation of biofilm on the metal surfaces by microorganisms. In the case of groundnut paste environment, the corrosion rates of mild steel coupons after thirty five days of induction were very minimal (Figure 1c). The highest inhibition efficiency was recorded when 15 g onion extracts were applied

(Figure 2c) thirty five days after induction. Corrosion rates in melon and cassava paste environments were similarly patterned, with least values observed in paste environments treated with 20 g onion extracts (Figures 1d & 1e).The inhibition efficiency values showed that 15 g and 20 g onion extracts gave the highest in melon and cassava paste environments respectively (Figures 2d & 2e). The inhibition efficiency records obtained in this study showed that thirty five days after induction, 15 g onion extracts, produced the highest inhibition of corrosion of mild steel coupons in cowpea, groundnut and melon paste environments. This observation suggests that the greatest inhibition of corrosion does not necessary occur at the highest concentration of onion extracts applied.







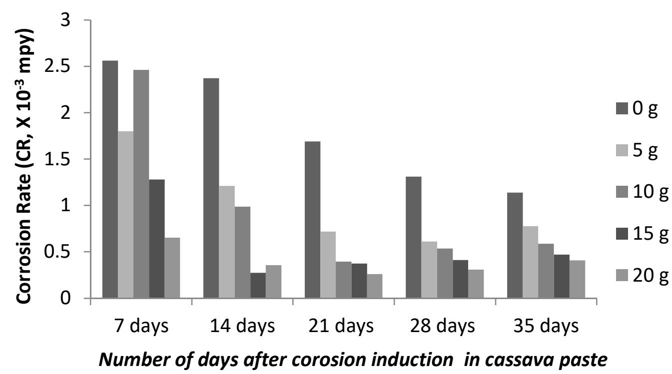
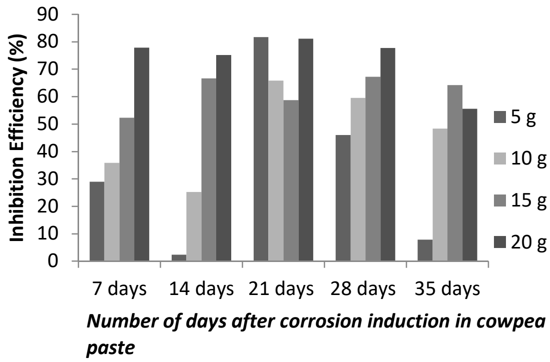
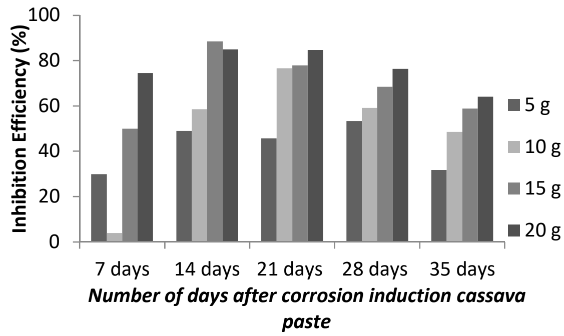
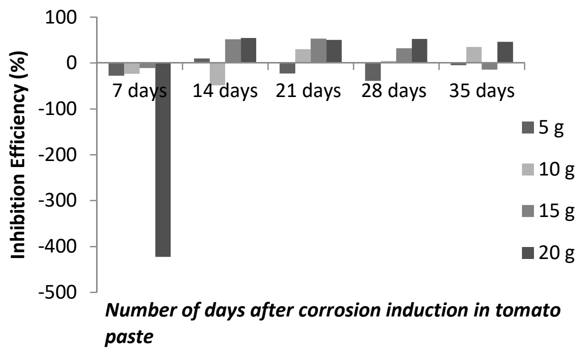
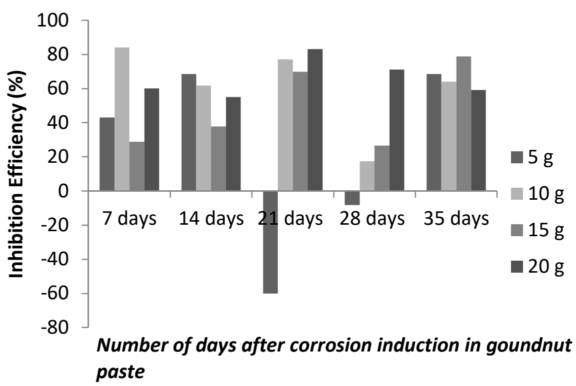


Figure 1: Corrosion rate (CR) of mild steel induced in (a) cowpea, (b) tomato, (c) groundnut, (d) melon, and (e)cassava food paste media, treated with different quantities of onion extracts as corrosion inhibitor









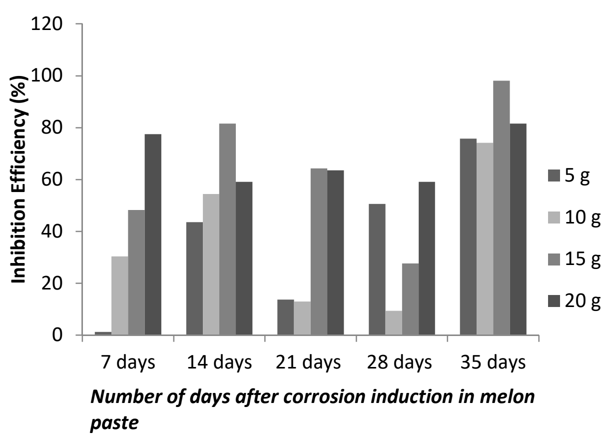


***Figure 2**: Inhibition efficiency (IE, %) of different quantities of onion extracts as corrosion inhibitor on mild steel corrosion induced in (a) cowpea, (b) tomato, (c) groundnut, (d) melon and (e) cassava food paste media*

Discussion

Scientists and researchers are challenged by the problem of metal bio-corrosion in different environments. One approach has been the suppression of microbial growth and metabolism in environments where metals are prone to corrosion. Oparadou and Okpokwasili (2014) stated that incorporation of biocide in soil environment reduced the population and species of bacteria and the bio-corrosion activity around and on steel coupons buried in the soil. The suitability of onion extracts as bio-corrosion inhibitor was emphasised by Koch *et al*.(1996) and Okafor *et al*.(2006). In this study, as immersion time increased, corrosion rate decreased. Morealso, higher the weight of inhibitor applied, the lower the corrosion rate and higher the inhibition efficiency recorded. The study suggests an inverse proportional trend between corrosion rate and weight of bio-corrosion inhibitor applied over time. Although, it is known that corrosion rate in mild steel coupons decreases with time because of growing biofilms by microorganisms, and reduced contact with the substratum. The study has also thrown up the opinion that mild steel coupons in the five food pastes did not behave alike during corrosion in the presence of the inhibitor. It is clear that the pattern of corrosion of mild steel may depend on the composition of the food paste. The inhibition efficiency estimated for mild steel coupons immersed in tomato paste was peculiar. The reason for this may be connected to the formation of biofilms and loss of direct contact with the mild steel coupons on the presence of the inhibitor. It should be noted that only two species of bacteria, *Pseudomonas* sp. and *Bacillus* sp., were recorded in the presence of the onion extracts.

Due to increasing environmental awareness, natural corrosion inhibitors are of great importance because of their biodegradability, easy availability and non-toxic nature (Taleb *et al.*, 2011). It was observed that the mild steel coupons turned brownish. Shinkafi and Dauda (2013) and Abdel-Salam *et al.* (2104) reported the antibacterial activity of onion extracts on selected pathogenic bacteria. In general, the corrosion rate of the mild steel samples decreases and the inhibition efficiency increases as the weight of the onion extracts increased. The decrease in the corrosion rate following increase in weight of onion extracts could be due to the formation of a protective external film by the higher concentrations of compounds present in the onion extracts. Onion extracts act mainly as a mixed type of inhibitor which was chemisorbed on the steel surface. Since the corrosion in food processing environment is usually more concerned with product contamination than with equipment failure, the presentation of corrosion data, in a form that gives the knowledge of the quantity of metal likely to be passed into the product as a result of corrosion is preferable. This has the benefit that with a knowledge of the chemical composition of the metal or alloy and assuming a uniform corrosion of all the constituent elements in the alloy, the elemental contamination in the food (or whatever product) can be estimated.

The results obtained from the microbiological analysis show that the bacterial loads in the five food paste environment without inhibitor had higher bacterial load than the five food paste environment with onion extract as inhibitor. The total viable bacterial counts in each five food paste environment treated with inhibitor (onion extract) ranged from 1.9×10^2 -3.2×10^3 cfu/g, while the total viable bacterial counts in each five food processing environment without inhibitor ranged 4.1×10^3 -9.9×10^3 cfu/g. The lower bacterial counts in five food processing environment with onion extract as inhibitor may be due to the antibacterial properties of onion extract on Gram negative and positive bacteria. The bacteria isolated from the five food processing environment with inhibitor were *Pseudomonas* sp., *Streptococcus* sp., *Micrococcus* sp., *Bacillus* sp., *Corynebacterium* and *Alcaligenes,* while the bacteria isolated from the five food processing environment without inhibitor were *Staphylococcus aureus*, *Micrococcus* sp., *Bacillus subtilis*, *Pseudomonas* sp., *Klebsiella* sp., *Serratia* sp. and *Escherichia coli.*

Conclusion

This study revealed the possibility of using onion extract as corrosion inhibitor for mild steel in food processing environments. The onion extract proved to be a good inhibitor with its efficiency increasing as the concentration increased up to 20 g. The decrease in the corrosion rate by onion extract may be due to the formation of a protective external film which contained compounds present in the onion extract. However, the inhibition efficiency decreases as the period of immersion increased indicating the reduction in the bioactive compounds in onion extract as results of microbial metabolism. The low bacterial loads in the five food processing environment with inhibitor could be due to the antibacterial properties of onion extract on both Gram negative and positive bacteria.

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