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Review Report

Corrosion of Household Utensils: Causes, Effects and Remedies

Liberty Kanyamumba[1], Chika O. Ujah[2]*, Daramy V.V. Kallon[2], Mohamed Dumbuya[3]

[1]Africa Centre of Excellence for Sustainable Power and Energy Development, University of Nigeria Nsukka, 410001, Nigeria
[2]Department of Mechanical and Industrial Engineering Technology, University of Johannesburg, Johannesburg 2006, South Africa
[3]Department of Chemistry, Njala University, Freetown 00232, Sierra Leone.

***Correspondence:** Chika O. Ujah**,** Department of Mechanical and Industrial Engineering Technology, University of Johannesburg, Johannesburg 2006, South Africa (Email: chikau@uj.ac.za).

Abstract: This article was motivated by the avalanche of finance spent annually on addressing the harm caused by corrosion on household wares and buildings, industrial machines and facilities, hospital equipment and many other establishment of man in the universe. Corrosion is a universal phenomenon referred to as the deterioration of metallic material. Metal alloys like stainless steel and aluminium are extensively used in household utensils for their durability, affordability and corrosion resistance. However, these materials can leach heavy metals such as chromium, nickel, iron, and aluminium into food, posing serious health challenges. Stainless steel, despite its corrosion resistance, releases harmful metals when exposed to acidic foods, while aluminium utensils corrode and release harmful elements under certain conditions too. Hence, this article was aimed at examining the historical background of corrosion, the causes of corrosion in household wares and utensils, its impact especially on human health and economy, and the potential remedies. The findings indicated that acidic foods and prolonged storage increase metal leaching. Health concerns included increased risks of anemia, dementia, and osteomalacia due to excessive metal accumulation in the body. Mitigation strategies included using anodized aluminium, minimizing storage time of acidic foods in metal containers, and increasing public awareness about the potential health risks. Proper maintenance and selection of utensils could significantly reduce the hazards associated with metal leaching.
Keywords: Corrosion, Leaching, Metal alloys, Stainless steel, Aluminium, Health risk

1. Introduction

Home utensils are vital instruments used daily for cooking, serving, and dining, ensuring convenience and efficiency in meal preparation, consumption, and storage. Alloyed metals, particularly stainless steel (SS), are commonly employed in cooking food, processing, and storage since they exhibit a property of corrosion resistance and barrier qualities (Zhang et al., 2022). Food contact (FC) SS objects are intended for long-term usage, but heavy metal migration poses a major safety issue when in contact with food (Zhang et al., 2022). Manganese is an essential alloying element in SS, and its potential migration has created significant consumption concerns. Stainless steel is easily damaged by organic acids, especially during storage. As a result, iron, chromium, and nickel have the potential to leach into food through cookware (Bassioni et al., 2014). Stainless steel cookware typically includes 18% chromium, providing optimal protection against corrosion. It also contains nickel which is roughly 8-10%, the two that is to say; Cr and Ni increase the ability of SS to resist corrosion and also makes it durable (Zhang et al., 2022). Some researchers suggest that stainless steel should have minimally 10.5% chromium and not beyond 1.2% carbon. During melting, additional elements like nickel, molybdenum, columbium, or titanium might change the properties. SS cookware takes up to 43% of all cookware (Bassioni et al., 2014). So, in the process of preparing and storing of food items in metallic cookware, considerable amounts of hazardous components can seep out and raise the uptake of metal beyond the allowable levels of intake per day, moreover in highly-regulated and hygienic households (Bassioni et al., 2014). Another category of household utensils is that of aluminium utensils. Aluminium utensils/cookware are extensively employed in least developed nations for home use, large scale cooking, schools as well as food preparation and packaging in developed and un-developed nations (Gupta et al., 2019; Yang et al., 2014). Figure 1 shows some household utensils.

Figure 1: Aluminium cookware (Gupta et al., 2019)

Aluminium is the most suitable material for kitchen utensils. Aluminium and its alloys are commonly utilized in various ways, including but not limited to, building, electricity (Ujah et al., 2022) and vehicles, aerospace, and in the production of cookware and food packaging. Aluminium's high utility stems mostly from its extraordinary characteristics. In poor countries, craftsmen exploit the characteristics of aluminium to create culinary tools for cooking and packaging food (Joshi et al., 2003). On top of the above advantage, aluminium pose other advantages like; Aluminium is the most suitable material for kitchen utensils. Aluminium's high utility stems mostly from its extraordinary characteristics. In poor countries, technicians utilize the unique characteristics of aluminium to create wares for cooking and packaging food (Ndem et al., 2022).

Aluminium’s tendency to corrode in aqueous conditions has been extensively investigated, and it is thought to be the cause for material degradation. Aluminium corrosion starts with attacking of the protective film (Al_2O_3) that covers it when exposed to air (Joshi et al., 2003; Noemie et al., 2022; Ujah et al. 2023). Many creative culinary utensils are fashioned from recycled materials, including automobile wrecks, construction components, tin cans, electrical cables, among others. Aluminium is the primary component of these sorts of garbage. The usage of aluminium utensils is a major contributor of human intake of aluminium (Sawadogo et al., 2018). Handmade aluminium kitchen equipment are prevalent in kitchens for the purpose of preparing and storing food, however they corrode if they get in touch with acidic and alkaline solutions like tomato sauces and salty water (Ramdéde et al., 2011). Aluminium materials' deterioration causes the flow of some of its constituent elements into the surrounding aqueous medium, hence the corrosion of aluminium. According to studies, the release of aluminium in cookware varies according to temperature, duration of cooking, aggressiveness brought up by cooking surroundings, quality of used or un-used utensil, and the dish's topography. The strong solubility of aluminium in cookware is a generator of heavy metals when acidic food is cooked for a while (Noemie et al., 2022). Important to note is that the release of such heavy metals is accompanied by corrosion of the metal.

There is a serious health challenge when we are exposed to an excessive level of metal or when there is a high level of their accumulation in the body. For aluminium, it should not exceed 1 mg/kg body weight in a 60-kg adult. For other heavy metals, this quantity is already in excess. This being that they are causative agents of certain diseases like anemia, dementia, breast tumor, colon cancer, Alzheimer’s disease, aluminosis and so on (Klotz et al., 2017), which are even more deadly than laboratory, road or home accidents (Ujah 2023). Therefore, it is important to undertake a study on the possible ways to avoid these metals being ingested into our bodies through the use of metal utensils in our homes; and ways of reducing corrosion in our household wares as corrosion is a major emitter of these metals. So, the motivation of this study was to engage in a study of the causes of corrosion in our household wares, and the ways of mitigating them. When the research finding precautions are adhered to strictly, the metal poisoning will drastically reduce.

1.1. Statement of Problem

Home utensils that are commonly made from metal alloys like stainless steel and aluminium are essential for home use in cooking, serving, dining as well as food storage. However, these utensils are somewhat exposed to corrosion as a result of interaction with food which raises significant concerns as a result of potential leaching of heavy metals like Fe, Cr, nickel, and aluminium into food. Stainless steel, commonly used for its corrosion resistance, can leach these metals as a result of corrosion, especially when in contact with acidic foods, posing health risks. Similarly, aluminium utensils can corrode and release harmful elements under certain conditions. This study aimed at investigating the causes of corrosion in utensils, its impact as well as the possible solutions/best practices for using metal utensils in homes.

1.2. Purpose of the Study

The general purpose of this research is to study the corrosion of household utensils; Specific purpose is to:

(a) Find the specific causes of corrosion on our household utensils
(b) Identify the effect of the damage wrecked by corrosion
(c) Proffer some solutions to mitigate corrosion on our household utensils

1.3. Review Questions

The following review questions guided the study:

(a) What are the possible causes of corrosion of utensils in homes?
(b) What the effects of corroded/corroding utensils?
(c) What are the possible remedies to corrosion of home utensils?

1.4. Review Motivation

This review article was motivated by several factors, which are discussed in this subsection. Corrosion is a universal phenomenon that is costly to address, and it should be thoroughly studied to reduce its negative impacts and minimize its occurrence. This study aims to provide readers with safety measures against the corrosion of household utensils, as the corrosion products can be harmful to the health of humans, animals, and the environment. Having adequate knowledge of corrosion will enable the general population to adopt practices that can prevent corrosion, thus, avoiding the need for frequent replacement of corroded household items, which can be expensive. Corrosion can lead to the contamination of food and water. However, having sufficient information about corrosion can improve public health by promoting adherence to precautionary measures and healthy practices that discourage corrosion. Through recommending further studies after the review, future researchers can be informed of gaps in current research that they can address.

2. Materials and Methods

2.1.1. Ethics Statement

There was no ethical concern in this review article.

2.2. Methodology

2.2.1. Protocol and registration

The protocol of this review article was created as a scoping review.

2.2.2. Eligibility criteria

The literature search was on peer-reviewed journal articles and conference papers. The selection of studies was based on materials published in Scopus database. The initial selection was not time dependent. It was initially based on published materials on Scopus database that dealt with corrosion of household items, cause, effects and remedies of corrosion of household items. After all the published materials were obtained, they were screened based on their publication date and relevance to the topic. Obsolete publications were discarded because the information therein may have been upgraded or discarded.

2.2.3. Selection of sources of evidence

The selection criteria were based on the date of publication, the relevance of the information contained in the research material and the usefulness of the information to the study aim. When there are multiple materials discussing one particular theme of the study, the most recent article was chosen.

2.2.4. Data items

The variables used in sourcing for study material are as follow: a) corrosion overview, b) overview of household utensils, c) household items prone to corrosion, d) manifestation of corrosion on household utensils, e) causes of corrosion on household utensils, f) control and prevention of corrosion, g) materials for storage of food items, h) contaminants to food items, i) effects of corrosion, j) precaution to prevent contamination of food items by the storage media.

2.2.5. Critical appraisal of individual sources of evidence

Information obtained and reported were subjected to double checking with what other researchers in the same field had said before. No information was reported without searching for the authenticity of the claim by other specialists in that field. Figure 2 summarizes the prism flow diagram used in the study.

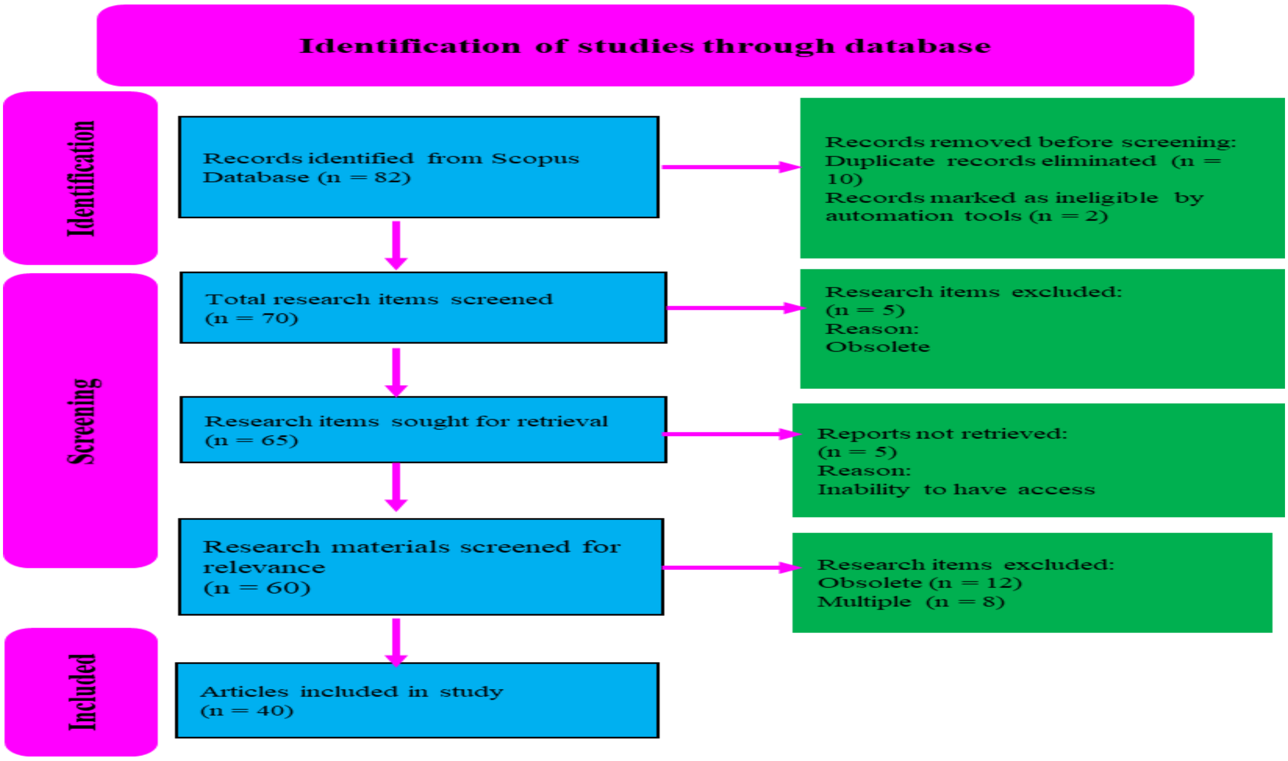

Figure 2: Flow Chart Diagram of Research Methodology

3. Results and Discussion

3.1 Causes of corrosion of household utensils.

As already discussed earlier that household utensils are majorly made from stainless steel and aluminium, this section thoroughly discusses the causes of corrosion for the two basic materials.

(i) Storage time and pH*:* The levels of Cr, Ni, and Fe leaching from SS cookware into food is dependent on the pH and duration the material has been subjected to the corroding media. An increase in the storage time lead to an increase in leaching of metals in all the fruit juices that were researched on by Bassioni et al. (2014). Important to note in this case is that leaching of these metals is accompanied by corrosion of the very metal. A study by Bassioni et al. (2014) on such was as shown in Table 2 and Figure 3.

Table 2: Chemical composition of stainless-steel grade 201 (WT %) (Bassioni et al., 2014)

C	Cr	Ni	S	P	Si	Mn	N	Fe
0.15 max	16.0-18.	3.50-5.5	0.03 max	0.060 max	1.00 max	6.50-7.5	0.25 max	Balance

From **Error! Reference source not found.**, it can be seen that pitting corrosion is visible on various areas of Figure 2b-e. It can be seen that the damage in Figure 2b is not as severe as in Figure c, d and e. There was outstanding damage in the surface exposed to strawberry in Figure 2e which manifested as pitting corrosion. The impact of strawberry juice on metal leaching is well visible in the stainless steel (Bassioni et al., 2014)

(ii) Various researches have also been made on corrosion of aluminium utensils. Several of these have revealed leaching of aluminium from cookware, although this phenomena depends on many conditions like pH, temperature, cooking medium, composition of food, time taken while cooking, and the prevalence of fluoride, sugar, salt, and organic acid (Al Juhaiman, 2012; Al Juhaiman, 2010) Gravimetric and atomic absorption methods were used to quantify the levels of aluminium leaching from cooking utensils and approximated the aluminium content in vegetable extracts that were used in the experiments, boiled meat, liquid fresh milk, and long-life milk. They discovered that the quantity that leached from the cookware into various samples was varying and depending on the aluminium content, type of extracts, water quality, table salt, temperature, and immersion time (Al Juhaiman, 2012; Al Juhaiman, 2010; Yang et al., 2014). A different study by Noemie et al. (2022) aimed to investigate the impact of two common Congolese condiments on the deterioration of kitchen equipment crafted from Congo Brazzaville. The quantification of loss in mass in culinary settings demonstrated that the material's ability to resist corrosion emerges in a consistent order with respect to the silicon concentration in the samples and the culinary environment. The study found that chloride ions (Cl^-) cause aluminium surface deterioration by destroying the protective layer, resulting in mass losses

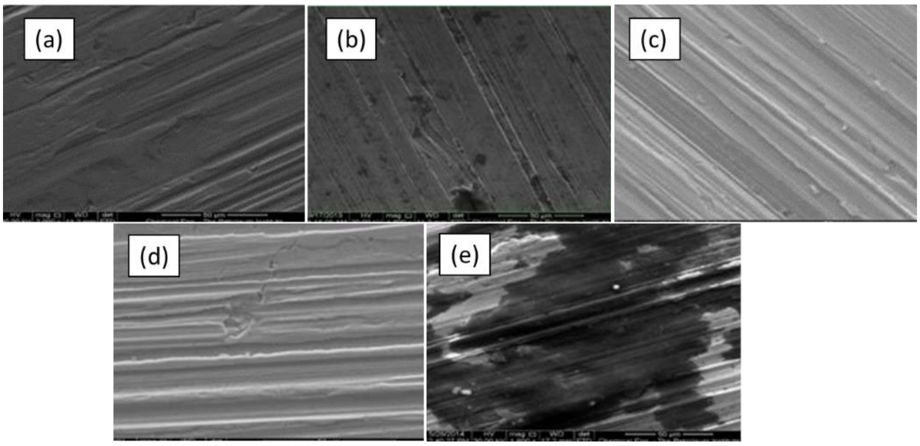

Figure 3a-e: Scanning Electron Microscope (SEM) Images of Stainless Steel Samples Subjected to Corrosive Food Items, (a) SEM of Stainless Steel Grade 201 (untreated), (b) SEM Image of SS 201 Exposed to Lemon Juice for 5 days, (c) SEM of SS 201 Exposed to Orange Juice for 5days, (d) SEM of SS 201 Exposed to Mango Juice for 5 days, (e) SEM of SS 201 Exposed to Strawberry for 5 days (Bassioni et al., 2014).

3.2 Effects of corrosion of household utensils.

The search mostly focused on the effects of corrosion of household utensils on humans. Various results were obtained as follows.

(i) A study was performed by Bassioni et al.(2014) on the effects of various pH levels as well as different storage intervals for four varieties of juices and were evaluated in terms of metal leaching from new stainless-steel cookware. interestingly, the human intake of Ni, Cr, and Fe at the end of the experiment (for lemon) were quantified to be 3.96, 0.48, and 36.57 mg per person, respectively. This intake exceeds the limit set by the World Health Organization. Other samples of the juices experimented are well explained by same author. SS utensils have been deemed an overlooked source of the said metals, where the impact is based on the SS quality and the duration stored (Bassioni et al., 2014). The same study revealed the rates of corrosion for the five samples and the results clearly explained and detailed by the author on page 8 of the journal article.

(ii)As a result, iron, chromium, and nickel are being studied for their ability to leach into food via cookware. Toxicological studies show that increasing dosages of metals like Ni and Cr can produce unpleasant reactions like dermatitis (Bassioni et al., 2014)

(iii) Aluminium leaching from cooking utensils and aluminium foils may induce ailments such as anemia, dementia, and osteomalacia, raising worries about its long-term safety in humans (Kawahara et al., 2007). Aluminium is known to accumulate in tissues and organs, which can cause malfunction. However, the issue is more pressing in people having chronic kidney disease (Elif Inan-Eroglu, 2018).

(iv) Aluminium is predominantly eliminated by the kidney; hence its buildup is a major issue in people with compromised renal function (Savory, 1989)

(v) Aluminium-containing medicines were once a therapy option for hyperphosphatemia, however they are no more routinely utilized due to toxicity concerns. When chronic dialysis therapy is initiated in CKD patients, aluminium poisoning with an elevated risk of morbidity and mortality in individuals

with uraemia can occur (Malberti, 2013).
(vi) Although aluminium has no physiological role, it has been linked to a variety of negative impacts where it is linked to osteomalacia (aluminium bone disease), dialysis encephalopathy, and anaemia (Kawahara et al., 2007).
(vi) Preparation as well as storage food in aluminium foil form a high contributor of aluminium exposure in affluent countries. Findings from Ranau et al. (2001) indicate that aluminium leached from the aluminium foil into the food, however, the extent of the leaching was determined by a number of factors (Joint FAO/WHO Expert Committee on Food Additives (JECFA), 2023).

(vii) Foodborne diseases (FBD) are a significant public health issue worldwide, causing emotional misery, premature deaths, and an unnecessary economic cost (da Silva Farias et al., 2019; Parra et al., 2014). Some of these foodborne diseases are directly linked to heavy metals that leach directly into the food.
FBD poses a significant global burden, yet the extent of hazardous food and its impact on public health remains unknown. FBD affects at least 2bn people worldwide annually, making it one of the most significant public health issues today (Draeger et al., 2018; Dimos Paraskevas, Karel Kellens, Wim Dewulf, 2015). It is important to note FBD are not fully reliant on corrosion of household utensils, however much they give a significant contribution towards such. FBD affects at least two billion people worldwide each year, making it one of the most serious public health issues of our day (Havelaar et al., 2015; Thomas et al., 2015; Scallan Walter et al., 2011).

3.3. Remedies to corrosion of household utensils

(i) Alloying and anodizing aluminium: When properly alloyed and anodized, aluminium can withstand corrosion to a greater extent (Davis JR, 2013; Yang et al., 2014). Anodizing cooking utensils will increase the oxide's thickness layer which protects it against corrosion, that would have enhanced leaching of the element into food (Mohammad et al., 2012)
(ii) Increased storage time increased metal leaching in all of the fruit juices that were considered in experiments. This was in accordance to Bassioni et al.(2014). The acquired results need heightened society awareness towards the use of SS with highly corrosive fluids and the associated prospective health concerns and henceforth need to reduce storage time of juices in stainless steel containers.
(iii) In reference to study by Semwal et al. (2006), the levels of aluminium leaching from anodized cookware is the same as that from SS utensils. The author concluded that if the producers of aluminium cookware follow the Bureau of Indian Standards, there would be no chance of detrimental impacts health of humans by cooking meals with aluminium utensils and using aluminium foil.
(iv) Another fundamental aspect to remember would be how to clean aluminium cutlery. Cookware must be washed using gentle materials, and caution should be paid to keep the protective anodized layer. Manufacturing companies recommend that these utensils should not be cleaned with a harsh or metal-based scrape (Gupta et al., 2019)
(v) To avoid discoloration, hand washing is recommended. If the cookware is stained, use a tiny amount of cooking oil and spread it evenly on the surface. Heat the cookware in the oven or on the

stove until fairly hot. Turn off the heat and let the pan cool fully. Repeat this process twice more, and the cookware will be ready to use in your commercial kitchen (Gupta et al., 2019).

(vi) Do not leave food in the cookware overnight. Storing food in cookware will cause stains or discoloration. The cookware is not designed to store food. Food held in cookware for an extended amount of time may alter the surface and cause it to taste metallic.

(vii) A study conducted by Ndem et al. (2022), when beans were cooked in both aluminium and SS cookware, it was discovered that aluminium cookware released far more trace elements than stainless steel cookware. The discharge of such components is followed by metal corrosion; hence it is recommended to use stainless steel cookware rather than aluminium cookware.

Based on the above findings, it is suggested that the following precautions must be abided by to avert possible challenges accruable from corrosion of kitchen/household utensils. A hybrid pot is recommended as the best pot for cooking. In this innovation, the core is made of aluminium which possesses higher thermal conductivity than stainless steel (Carvalho, Galvão, Mendes, Leal, & Loureiro, 2018), such that heat input will be transferred to the food with less resistance. The outer and inner surfaces are made of stainless steel which has better shinning, less-reactive and better abrasive property than aluminium. The hybrid pot gives the optimal performance that cannot be obtained from either aluminium or stainless steel pot. The hybrid pot is as shown in Figure 4.

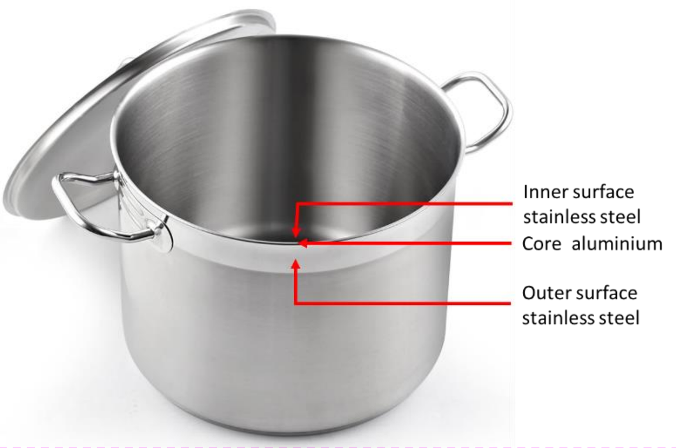

Figure 4: Hybrid Pot

Food storage ware is another aspect that needs to be considered. There are three popular materials used in storing food. Plastics, stainless steel and glass. Plastic is cheap, light in weight but it has many limitations. It absorbs food odor, it leaks poisonous substance when cracked, it is prone to abrasion and it absorbs stains (Deshwal & Panjagari, 2020). For stainless steel, it is resistant to odor, stain and abrasion but it is not transparent (Badilla, Salas, & Wiener, 2012). Stainless steel cannot be used for microwaving foods as it is conductive to electricity and heat. The best choice for food storage is glass because it has the properties deficient in both plastic and stainless steel. It is heat resistant, and so, can be used in the microwaves, it does not leak poisonous substances and it is resistant to abrasion, odor and stain (Debeaufort, 2021). Though the only challenge is that it is heavy, so it is better used to store foods in the fridge than for transporting food. So, for storage in the fridge, glass is the best, for transporting food, new plastic container without cracks should be used, for dishing out food, stainless steel can be used. The three food containers are shown in Figure 5. The following are some precautions to be taken when using plastic containers: i) Fatty foods including meat and fish should not be stored in plastic containers that contain bisphenol A (BPA) or phthalates as the chemical can react with them (Fasano & Cirillo, 2018). Ii) Acidic food such as those containing tomatoes and citrus can react with plastic container made of polyvinyl chloride (PVC), and result to food poisoning (Lahimer, Ayed, Horriche, & Belgaied, 2017). So, PVC plastic containers should not be used to store acidic foods. Iii) Non-heat-resistant plastics should not be used to store hot foods because it can distort the container and stimulate the release of harmful substances to the food. When using stainless steel containers, the following precautions should be adhered to: i) Table salt (sodium chloride) is corrosive to stainless steel. So, highly salty food should not be stored in stainless steel container as this will induce corrosion and subsequent contamination of the food (Subari, Maksom, & Zawawi, 2015). Ii) Acidic foods are reactive to stainless steel containers. So, foods containing tomatoes, vinegars, citrus, etc should not be left for a long time inside a stainless steel container (Petrovič & Mandrino, 2016). Iii)

Figure 5: Three Different Food Storage Containers

3.4. Further studies

There is the need for further laboratory characterization and testing of the household utensils' corrosion characteristics in various media, viz, acid, base, salt and neutral. The results obtained would be published in peer-reviewed journals, communicated in radio and television jingles, social media platform and so on. This would help in educating the general publics on materials suitable for certain applications, such as, food storage, water storage, cooking, eating, etcetera. Through educating the general public, the harmful effects of corrosion on household wares would be reduced.

4. Conclusion

The use of metal alloys such as stainless steel and aluminium in household utensils is widespread due to their durability, affordability and corrosion resistance. However, these materials pose significant health risks due to the potential leaching of heavy metals such as chromium, nickel, iron, and aluminium into food. Stainless steel, often chosen for its resistance to corrosion, can still release harmful metals when in contact with acidic foods. Similarly, aluminium utensils are prone to corrosion and can release toxic elements, particularly in acidic or alkaline environments. Research findings showed that prolonged exposure to acidic foods increases metal leaching, raising concerns over long-term health effects such as anemia, dementia, and osteomalacia. Solutions included using anodized aluminium and reducing the storage time of acidic foods in metal containers to minimize metal leaching and its associated health hazards. Further research on exposure of metal alloys used in household wares to other corrosive media like alkaline, salt and neutral was recommended in the research.

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Conflict of Interest
There is no conflict of interest whatsoever.

Author Contributions
COU conceived, analyzed, supervised the research and submitted the manuscript; LK conducted, analyzed and drafted the research findings, DVVK and MD analyzed, reviewed and edited the research.

Data Availability Statement
There is no data applicable to this research.

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