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Assessment of Alkaline Food Environment Corrosion with Some Menus at a Cadets Mess on the Tensile Strength of Aluminum 6063 Alloy

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Abstract: The prominent demerit of aluminum as a food grade material is its low tensile strength and impact tolerance with greater liability to break compared to other common food grade metals. It is reaffirmed that aluminum can corrode appreciably in alkaline environments with pH greater than 9 and exacerbate its weakness in strength and frequent intake of its ions along with food into the human body due to corrosion or other means can be health-hazardous. Aluminum containers were seen to be in use for preparing and serving various menus from the general Nigerian diet to about 1000 cadets on daily basis at Nigerian Defence Academy (NDA) cadets' mess. The menus and various ingredients used for them amidst the general mess environment were seen to be inevitable of ability to corrode the containers. The paper was a search through accelerated corrosion test to understand whether some of the commonly prepared and served menus at the mess namely; Eba, fried rice, Egusi soup, tomatoes stew, Alayafu vegetable dressings, and their possible different combinatorial admixtures amidst any alkaline environment had severe corrosion effects on the tensile strength of the containers. 64 ASTM standard tensile samples of aluminum 6063 as a commonly used food grade alloy for such containers were procedurally produced and prepared for the study. 62 of the samples were subjected in pairs to some similar and alkaline treatments that mimicked alkaline environment corrosivity extremity of each menu to the containers. Thereupon, the samples were tested of their ultimate tensile strengths (UTS) and results collated and reported as the respective average pair values. Analysis of the reported results relative to that of the control sample pair showed negligibly small tensile strength reductions of 0.00027% to 0.00135%. Further analysis using literature facts understandably indicted that the menu samples amidst the mess environment have negligible effects on corrosion and tensile strength of the containers and health of the cadets.

Keywords: Nigerian diets, corrosivity levels, alkaline peculiar environments, Nigerian Defence Academy (NDA) cadets' mess, cookware corrosion deterioration, cost implications, test information, applications.

I. INTRODUCTION

A. Background to the Study

Corrosion is the natural process of interaction of an engineering construction material especially metal with its environment resulting in deterioration of its properties and service attributes [1, 2]. All environments other than vacuum can be corrosive at various levels to different metals. Corrosion directly or indirectly affects everybody, community, nation, and all spheres of human activity. The total cost implications of metallic corrosion on technological and economic development as well as environmental and personal safety are huge and staggering [1, 2, 3].

The food sector is a critical one since every one out about seven billion humans on this planet eats. Overall, corrosion has been lurking threat to the success of food manufacturers in the sector across the world. The present total direct annual cost of corrosion to the food industry is estimated to be over $2.1 billion based on the National Association of Corrosion Engineers report for corrosion costs in 1999 [4, 5]. Continued research knowledge and application to preventative measures, such as proper facility design and use of materials with properly applied protective coatings is therefore seen to be crucial for reducing the threat and cost of corrosion damage to food contact metals. According to the Food and Drug Administration (FDA), to be considered food-safe, a material must meet several conditions [6, 7, 8]. For example, it:

1) Must not allow the migration of deleterious substances or impart colors, odors, or tastes to food.
2) Should be durable, corrosion-resistant, and nonabsorbent.
3) Should possess sufficient weight and thickness and strength to withstand repeated ware washing and forces.
4) Should be well finished to have a smooth, easily cleanable surface.
5) Should have resistance to pitting, chipping, crazing, scratching, scoring, distortion, and decomposition.

Any material can be used for food handling if it is covered with a protective coating that is health-safe to human and can withstand aggressiveness of corrosion for food serviceability applications. But the bulk of materials used in food handling and processing are stainless steel at top scale and aluminum. The key advantages of aluminum as a food grade metal are its temperature tolerance, ability to heat and cool quickly, light weight, rust corrosion resistance, low cost, and good formability properties. However, many of the formal inquiries into aluminum as food contact material are that it is softer and able to withstand less abuse, it has low tensile strength so can't take much stress before breaking, intake of its ions in the body system can cause liver toxicity and lead to degenerative symptoms including Alzheimer's disease, and it can change the appearance of food and influence the way food tastes

for an extended contact period compared to stainless steel and most other food metals. Also, aluminum can corrode appreciably in highly acidic, alkaline, and chloride environments with exacerbation of all its disadvantages as a food contact metal [9-12].
Aluminum used to make cookware, utensils, and industrial food equipment is alloyed with other elements to give it strength and durability. Aluminum foil in the cooking industry also relies upon tensile strength to ensure that the foil is pliable enough to be easily maneuvered by hand. The same goes for soda cans. The main alloy elements used to impart strength and other properties of aluminum are manganese, silicon, iron, and copper [10]. The percentages present in each of these elements determine the aluminum grades' physical properties. For food handling, aluminum alloys also need to contain some elements in quantities that negate health risks. So when aluminum is used in the food industry, there are rules as to what the content of its alloys must be for applications. There are therefore maximum tolerances laid down according to European Food and Feedstuff law EN 602:2007 and other reputable authorities in connection with the use of aluminum in the food industry. The maximum allowable content of various elements in aluminum alloys used in the food industry are shown in Table 1 [4, 5]:

Table 1: The maximum allowable content of various elements in aluminum alloys used in the food industry [4, 5]

Element	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Zi	Ti	Balance
Max. content by mass [%]	13.5	2	0.6	4	11	0.35	3	0.25	0.3	0.3	0.15

B. *Statement of the Problem*

Aluminum and stainless steel pots, baking trays, cans, and pans are used to prepare large quantity of food for about 1000 cadets for breakfast, lunch and dinner on daily basis at Nigerian Defence Academy (NDA) cadets' mess. The prepared foods are also served to cadets with aluminum or stainless steel plates and fetched and put in mouth using spoons and cutleries made of the same types of metal. The foods are cooked by heating them to various temperatures between about 100 to 150^{O}C and durations of 30 minutes to two hours depending on the types and quantities of the food. Some of the mess food products require mixing with ingredients that contain various levels of chemicals like alkali, chlorides, organic acids, sodium bisulfite, potassium bisulfite and sodium sulfite, which are generally known to be corrosive to metals. The most commonly used corrosive element at the mess kitchen is water. Steam heating, cooling and other processing and cooking procedures at the mess require continual use of water. Facility cleanliness is also crucial part of the mess, so daily sanitization processes are conducted to meet the mess requirements, and large amounts of water are used in daily wash down procedures. These sanitation processes often use chemical cleaning solutions that can be corrosive to metals. Also, some of the mess foods per se can be corrosive. It is known that acidic or alkaline foods with pH of 3-5 or pH of 10-13 respectively are highly corrosive to aluminum metals [13]. The foods prepared and served to cadets at the mess reflect the Nigerian food recipes which are derived from a number of grains, rhizomes, bulbs, fruit seeds, vegetables and an avalanche of fruits. The food recipes come mainly from a selection of semi-solid dough or boiled servings prepared from cassava, plantain, yam, cocoyam, millet, beans, maize, or rice, served with typical Nigerian soups or stews. The soups and stews are generally a careful and deliberate blend of spices and seeds or thickeners in a broth enriched with fish and assortment of meats and leafy vegetables as desired. Meals are also served with plenty of fruits mostly of the citrus types easily grown near Nigerian homes. The foods prepared and/or served at the mess include:

1) Jollof or fried rice served with plantain (dodo) or tomatoes stew.
2) Akara made from soaked pealed beans (black eye beans) served with pap or Akamu.
3) Bread smeared with butter or margarine with fried, scrambled or boiled egg, and tea.
4) Moimoi and bread or pap with fresh fruits.
5) Fried or ripe plantain with boiled or fried eggs, and tea
6) Boiled yam and green plantain with pepper soup and fresh or dry fish or beef.
7) Boiled or fried yam with scrambled or fried egg.
8) Boiled rice and stew.
9) Amala made from ground dried yam with various soups.
10) Eba (made from grated fried cassava) with various soups.
11) Pounded yam with various soups such as Egusi, Ogbonno, or made from various vegetables such as okra.
12) Beans served with fried plantain.
13) Meats such as fried or boiled beef, chicken and goat meat used for most meals.
14) Fruits such as the citrus types.
15) Soups and stews prepared with ingredients that include pepper, table salts, magi, palm oil, groundnut oil, onions, ginger, Alayafu vegetable, tomatoes, and bitter leaf.

All these food types have different chemical compositions and properties and use of various ingredients and water during their preparation, chemicals during sanitary cleaning and other daily practices at the cadets' mess make them amidst their general preparation environment doubtless of inability to corrode cookware and other food containers thereat. Corrosion of the food containers can cause release of aluminum ions in the menus and reduce their durability and quality with increased costs. The aim in this paper is to present a study on effects of some commonly prepared and served menus at the cadets' mess namely; Eba, fried rice,

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Egusi soup, tomatoes stew, Alayafu vegetable dressings and their combinatorial admixtures amidst any alkaline mess environment on corrosion and tensile strength of aluminum 6063 alloy as a commonly used alloy to make aluminum food equipment, containers, and utensils. The specific objectives of the study were:

a) To use the results to understand whether the quality of aluminum cookware and utensils used to prepare or serve food to cadets at the mess is intact with respect to corrosion and tensile strength.

b) To have insight into the level of aluminum corrosion ions present in the food menu, since daily intake of aluminum ions due to corrosion or other means above 10 mg/Kg can affect the health of cadets [5, 14].

c) To posit any useful information for research interest and upfront consideration by manufacturers or producers of aluminum cookware and utensils such as pots, pans, plates, cutleries, cans and trays for any rethinking and action in quality control of their products..

II. METHODOLOGY

A. Procurement and Ascertainment of the Al 6063 Alloy

The alloy was procured in similar rods of diameters 15mm and lengths 3000mm from a commercial dealer in Kaduna, Nigeria. The rods were chemically analyzed to ascertain them using the energy dispersive X-ray fluorescence analysis by the Minipal 4 facility manufactured by Pan-analytical Limited Netherlands. Plate I shows a side view of the chemical analyzer and plate II the procured rods used. The analyses confirmed from literature facts [4, 5, 12] that the rods were indeed aluminum 6063 alloy with their average elemental weight composition as shown in Table 2.

Table 2: Percentage [%] average elemental weight chemical composition of the procured 6063 aluminum alloy rods

Element	**Fe**	**Mg**	**Cu**	**Si**	**Al**
Composition [%]	0.121	0.478	0.063	0.423	Balance

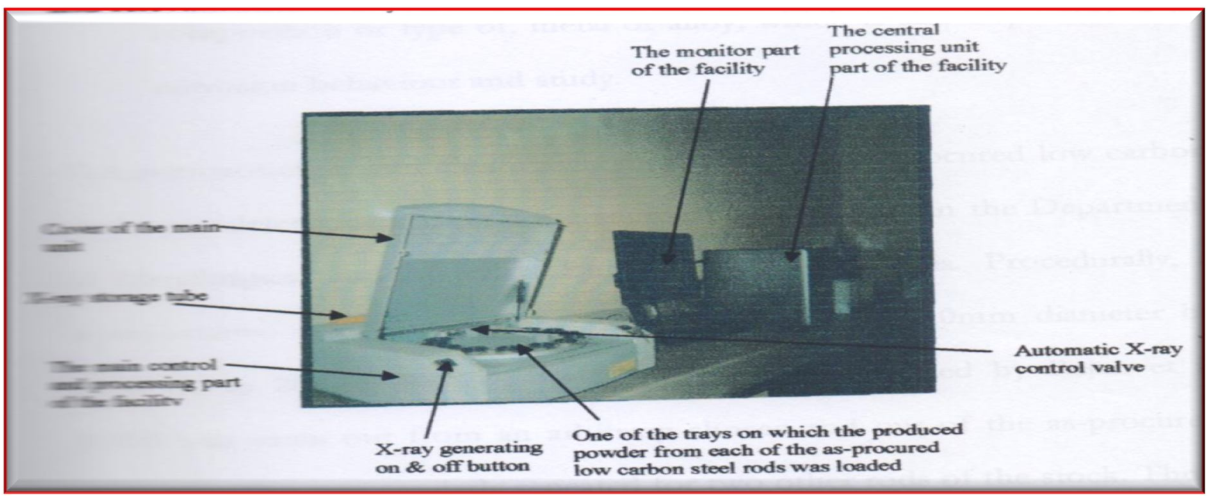

Plate I: A side view of the Minipal 4 facility used to analyze chemical composition of the procured Al rods

Plate II; The procured 6063 aluminum alloy rods used

B. Production of the test Specimens

The confirmed aluminum rods were used to machine-produce 34 pairs of the ASTM standard tensile specimens by sawing them out into lengths of 60mm and machining the sawn-outs on the lathe to the required shape sizes and gauge lengths of 50.8 mm and diameter 12.5mm as shown in Fig 1. Plate III shows the process of machine-producing the specimens on the lathe.

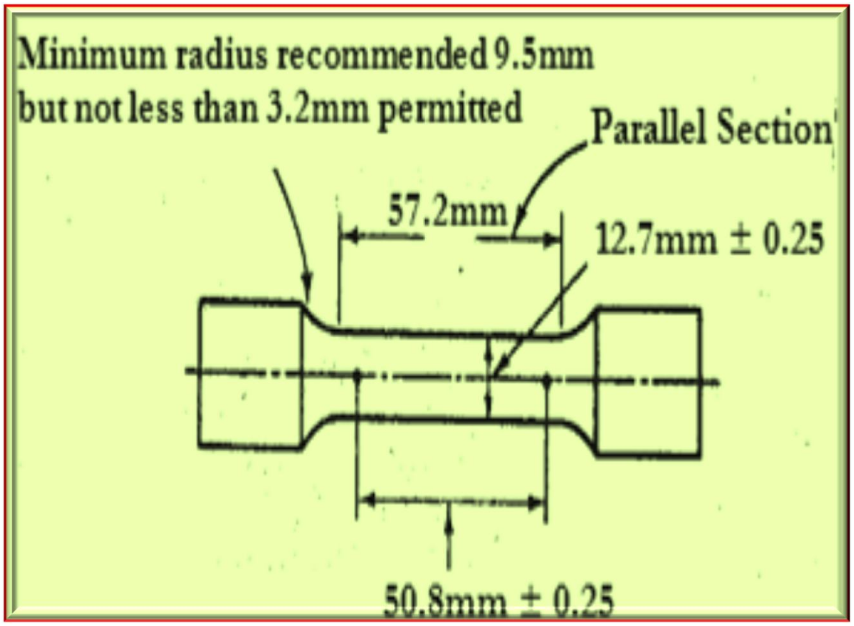

Fig. 1: ASTM standard tensile specimen [16]

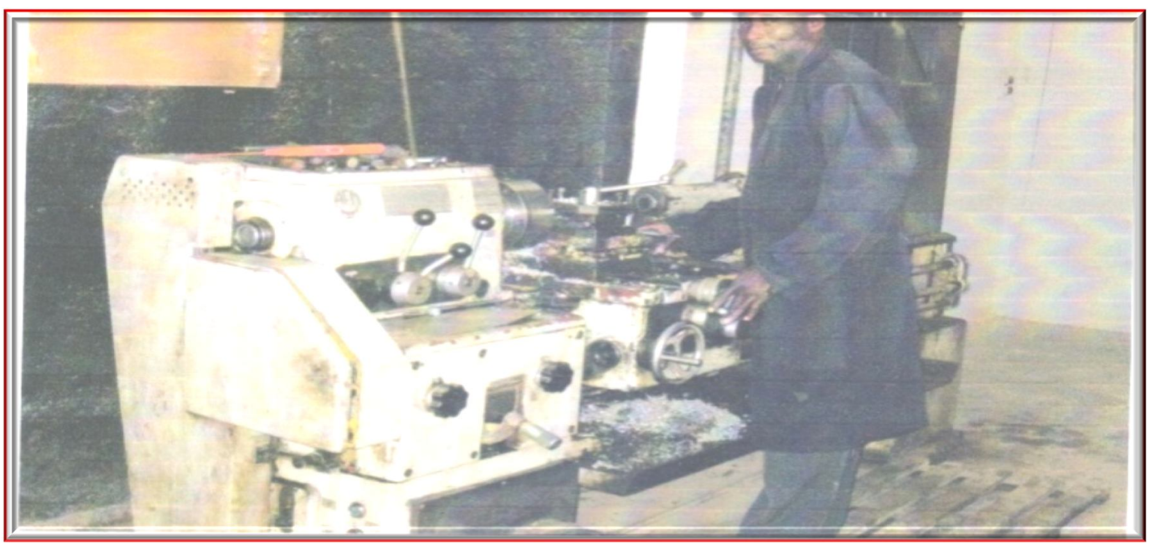

Plate III: The process of machine-producing the specimens on the lathe

C. Cleaning The Test Specimens

The specimens were cleaned to uniform smooth surface finishes in accordance to the ASTM G1-03 procedure for cleaning metals for corrosion tests [15]. By this, a smooth file was first used to scrub off all machining burrs on the specimens. The specimens were then successively cleaned manually with abrasive emery cloth of grit 280, 190, and 120. Attached particles onto the specimens were frequently brushed off with a clean hand towel during the process. The finally polished specimens were then rinsed under cold tap water and cleaned by dipping them into a solution of 70% HNO_3 in a 1000ml plastic beaker for 2 to 3 minutes at room temperature. The dip-cleaned specimens were rinsed in distilled water. After that the surface water on them was wiped with a lint free towel. Thereupon the specimens were suspended in an oven warmed to 52^{O}C to dry them. In all cases specimens were duly handled with gloved hands. Plates IV and V show some of the specimens after machine-producing them and after cleaning them respectively.

Plate IV: Some of the produced specimens before cleaning them

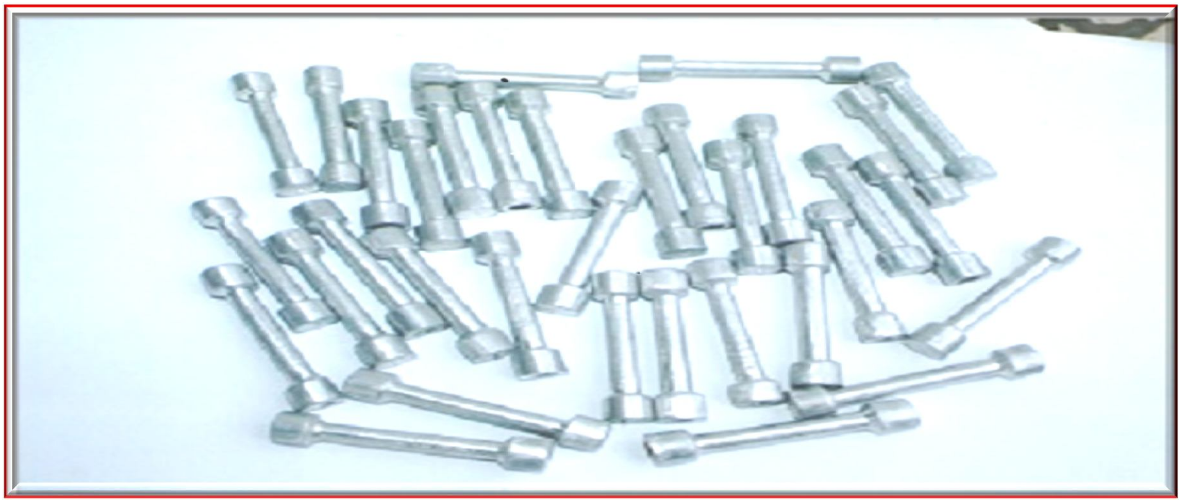

Plate V: Some of the specimens after cleaning them

D. Corrosion of test of the Specimens

Two of the prepared coupons were used as control (un-corroded) and tested of their ultimate tensile strengths immediately after preparing all the coupons. The other prepared coupons were first immersed in water and heated daily for two hours to the temperature of 200^{O}C using a 50kg-gas heating unit and aluminum pot got from NDA cadets' mess kitchen to simulate the usual cooking temperature exposure conditions at the mess on the coupons. Thereupon, the coupons were immersed in tap water mixed in a bowel with 3000ppm of Omo detergent and 600ppm of anal grade NaOH of pH 13 and cleaned with a usual sponge used for cleaning cookware at the mess and left there for 22 hours. This was done to simulate the worst possible effects of aggressive chemicals used in cleaning cookware and utensils at the mess on the coupons. This continued daily alternately in that order for 60 days with the assistance of some staff of the mess. Thereupon, the coupons were soaked in pairs continuously for 30 days under ambient laboratory conditions in Eba (B) , fried rice (R), Egusi soup (E), tomatoes stew (T), and Alayafu vegetable dressings (A) and various combinatorial admixtures of the menus, that is BR, BE, BT, BA, RE, RT, RA, ET, EA, TA, BRE, BRT, BRA, BET, BEA, BTA, RET, REA, RTA, ETA, BRET, BREA, BETA, BRTA, RETA, and BRETA media each homogenized with 800ppm of anal grade NaOH of pH 13 in separate clean plastic containers. Each admixture media consisted of equal proportion of the menus by mass and was made by weight determination using a digital scale and similarly mixing the constituents in clean plastic containers with aluminum spoon. Thereupon, the coupons were removed from the containers and tested of their ultimate tensile strengths (UTS) after wiping their surfaces with a velvet tower for better test handlings. The UTS were collated and reported as averages of the respective coupon pairs soaked in each prepared media. Plate VI shows the basic menus used for the study and Plate VII the coupons as soaked in the media in plastic containers in the laboratory with identification labels of the media on the containers

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Plate VI: A sample of the mess menus used for the study

Plate VII: Coupons as soaked in the prepared menu media samples inside some containers in the laboratory with the identification labels

E. Tensile Test of Coupons

The coupons were individually tested of their ultimate UTS at room temperature, using the Hounsefied tensometer manufactured by Tensometer Limited of England. Each sample was loaded on the tensometer and slowly subjected to increasing tensile force until fracture occurred. The load and extension were recorded automatically by the tensometer on special graph paper. The plots on the graph paper were used to obtain ultimate tensile loads and the loads converted to stresses by dividing each load by the initial cross sectional area the coupons. Plate IX shows the set up for the tensile test of coupon on the tensometer.

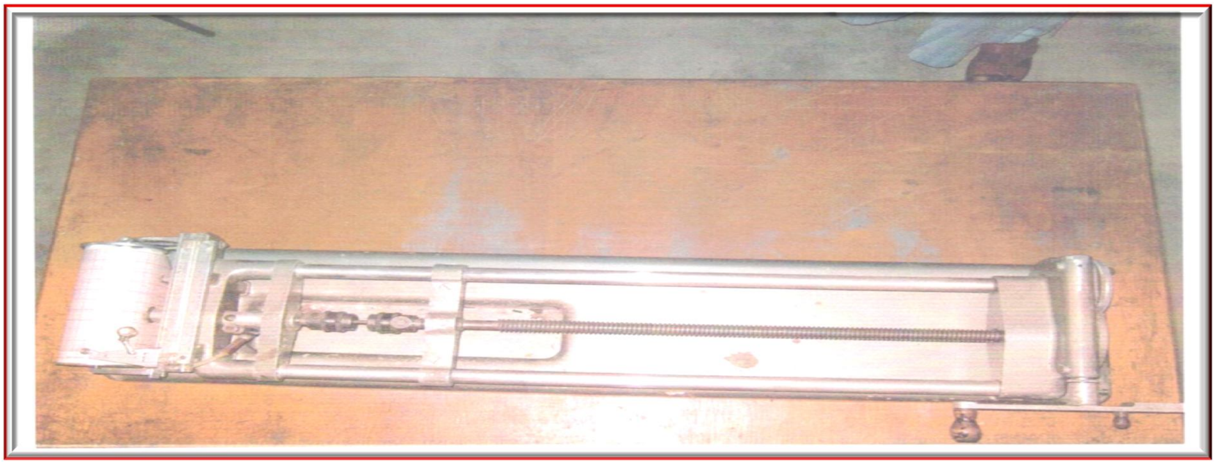

Plate IX: Tensile test of coupon on the tensometer showing the graph paper as it was used

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III. RESULTS AND DISCUSSION

A. Results

Results of the UTS of the 6063 aluminum alloy coupons for the simulated exposure to the NDA cadets' mess food environment as obtained by Jahleel Durami [16] are shown in Figs 2 to 6. The percentage corrosion reductions (CD) of UTS of coupons exposed to the menu sample media were evaluated according to equation 1 [17] and presented in Table 3.

$$CD = \left[\frac{UTS^C - UTS^E}{UTC^C}\right] 100\% \ \ldots\ldots\ldots\ (1)$$

Where $UTS^C, and\ UTS^E$ are the ultimate tensile strengths of the control coupons and coupons exposed to the mess environment and soaked for 30 days to the respective prepared menu media.

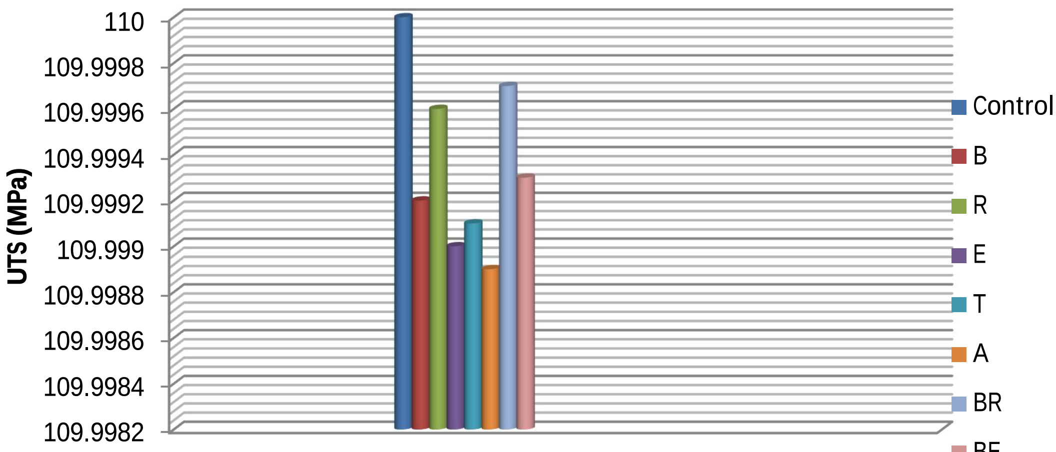


Fig. 2: Effects of some menu media samples and the simulated environment corrosion of NDA cadets' mess on the ultimate tensile strength (UTS) of Al 6063 alloy coupons

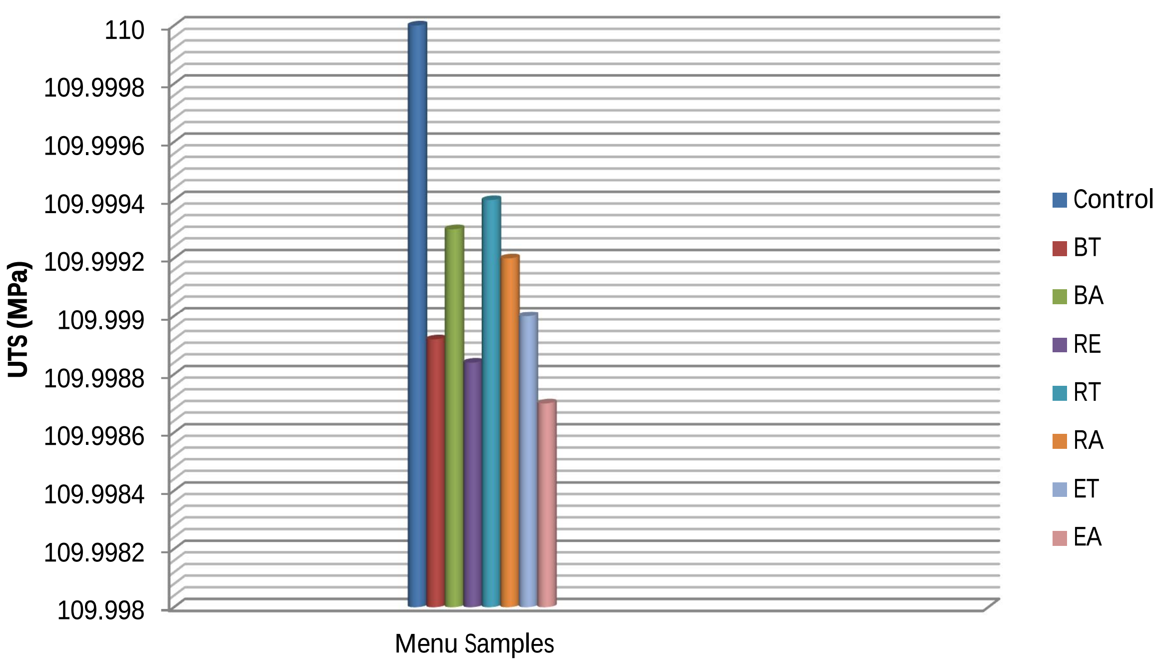


Fig. 3: Effects of some menu media samples and the simulated environment corrosion of NDA cadets' mess on the ultimate tensile strength (UTS) of Al 6063 alloy coupons

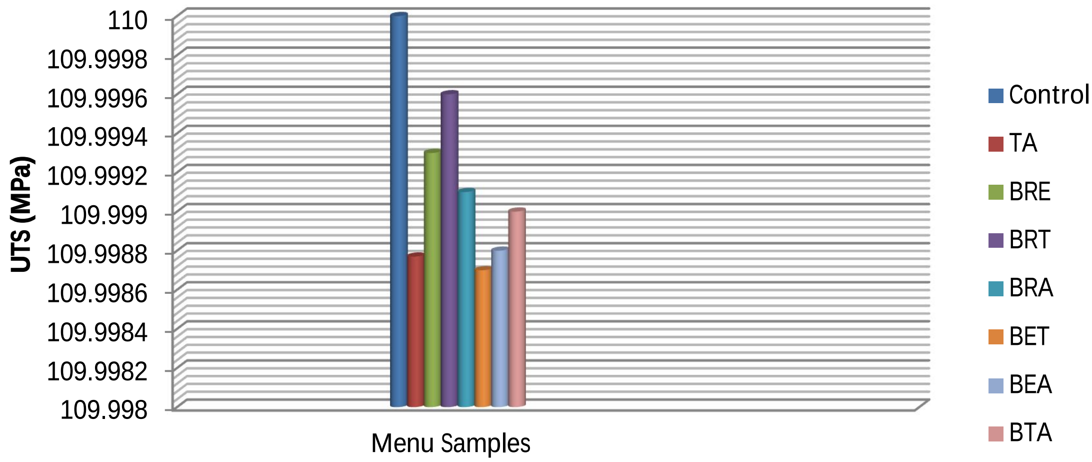


Fig. 4: Effects of some menu media samples and the simulated environment corrosion of NDA cadets' mess on the ultimate tensile strength (UTS) of Al 6063 alloy coupons

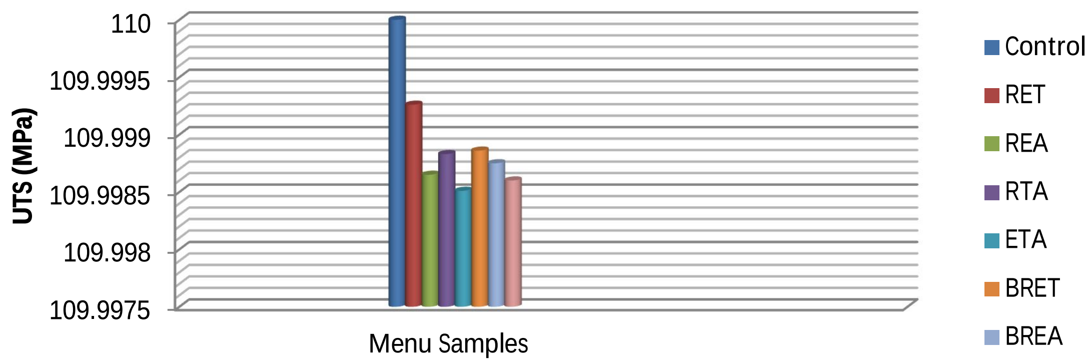


Fig. 5: Effects of some menu media samples and the simulated environment corrosion of NDA cadets' mess on the ultimate tensile strength (UTS) of Al 6063 alloy coupons

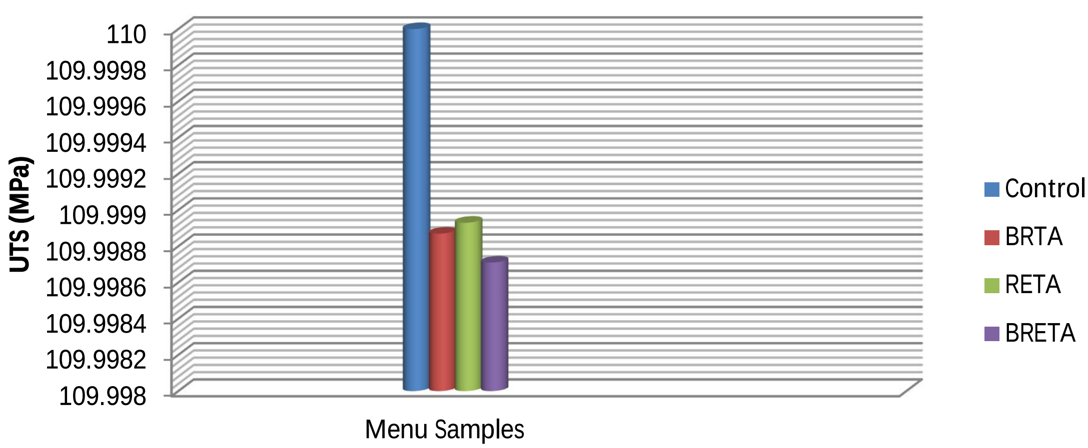


Fig.6: Effects of some menu samples and the simulated environment corrosion of NDA cadets' mess on the ultimate tensile strength (UTS) of Al 6063 alloy coupons

Table 3: Percentage corrosion reductions (CD) of UTSs of the Al 6063 alloy coupons after treatment to the simulated mess environment and then the prepared menu media samples as obtained by Durami [16]

Menu media samples	CD	Menu media samples	CD	Menu media samples	CD
B	0.000727	RA	0.00073	REA	0.00123
R	0.000364	ET	0.00094	RTA	0.0011
E	0.00091	EA	0.00118	ETA	0.00135
T	0.00082	TA	0.00112	BRET	0.00104
A	0.001	BRE	0.00064	BREA	0.00114
BR	0.00027	BRT	0.00036	BETA	0.00127
BE	0.00064	BRA	0.00082	BRTA	0.00103
BT	0.00098	BET	0.00118	RETA	0.00097
BA	0.00064	BEA	0.00109	BRETA	0.00117
RE	0.00105	BTA	0.00091		
RT	0.00055	RET	0.00067		

B. Discussion

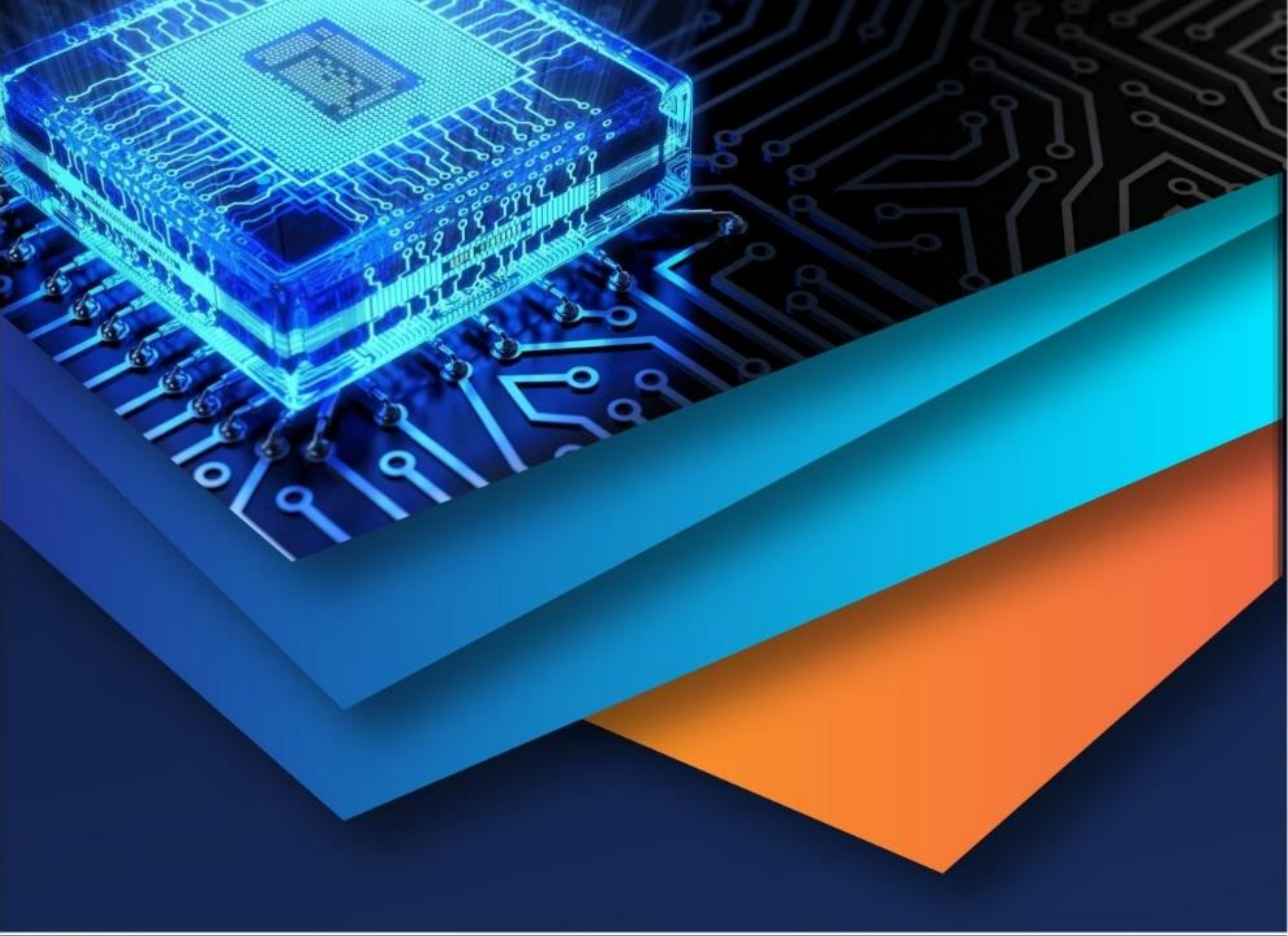
From results of effects of the prepared menu environment corrosivity levels on the UTS of the Al 6063 alloy coupons shown in Figs. 2 to 6 and Table 3, it can be seen that the menu samples had different effects on corrosion and UTS of the alloy samples by correlation with the 110-MPa UTS of the control coupons. The UTS of all the coupons ranged from 109.9997Mpa with the Eba-fried rice admixture (BR) media to 109.99851Mpa with the Egusi soup-tomatoes stew-Alayafu vegetable dressing admixture. These correspondingly caused reductions in UTS of the coupons relative to the control coupons by amounts that ranged from 0.00027 to 0.00135% by all the media samples as can be seen from Table 3. It can be seen that individually; the Alayafu (A), Egusi soup (E), tomatoes stew (T), Eba (B), and fried rice (R) menu media caused reductions of the coupons' UTS in decreasing order respectively as can be seen from Table 3. The Alayafu-Egusi soup-tomatoes stew media caused greatest reduction in the UTS of the aluminum coupons (0.00135%) compared to the other menu media. The reason attributed to this is that Alayafu, Egusi soup, and tomatoes stew are vegetable based menus and vegetables have pH in the range of 3.0 to 6.0 and are more acidic than rice and Eba which have higher pHs near neutral conditions [5]. So the same quantity of NaOH treatment all the menu media still made the Alayafu-Egusi-soup-tomatoes stew medium more corrosive than the rice or Eba media. By logical reasoning it is expected that the synergistic effects of Eba (E) and fried rice (R) should follow that pattern but the prepared media of the duo caused least reduction in the UTS of the coupons compared to Eba (B) and rice (R) per se as can be seen from Fig. 2 and Table 3. One reason that can be advanced for this trend of behaviour is that the two menu samples contain chemical species that turn to inhibit corrosivity of one another when mixed together. Aluminum and its alloys generally have good corrosion resistance in most environments. In a rural atmosphere, the corrosion rate for most aluminum alloys is approximately, 0.06µm/yr and is considered very insignificant. For aluminum alloys containing large amounts of copper about double this low rate is obtainable. Changes in tensile strength because of corrosion vary from 0 to less than 1% for Al sheet material [18]. Comparison of this fact with the reductions in UTS of the aluminum coupons by 0.00027 to 0.00135% which are insignificantly small, indicates that the NDA mess menu samples used for this study have insignificant effects on the tensile strength of the Al 6063 alloy coupons. This by implication also indicates that the menu samples have negligible effects on corrosion and tensile strengths of aluminum cookware and utensils used at NDA cadets' mess.

IV. CONCLUDING REMARKS

The costs of food environment corrosion with respect to aluminum equipment, cookware and utensils were recognized and explored. Aluminum cookware and utensils were seen to be in use for preparing and serving foods from the general Nigerian diet to about 1000 cadets three times on daily basis at NDA cadets' mess under peculiar environmental conditions. The paper sought to understand whether some commonly served menus-Eba, fried rice, Egusi soup, tomatoes stew, and Alayafu vegetable dressings and their different possible combinations amidst any alkaline environmental exposure at the mess cause severe corrosion and tensile strength reduction of aluminum cookware and utensils used at the mess. Laboratory tests of effects of some physically simulated environmental exposure conditions of the mess amidst alkali-accelerated corrosivities of the menu samples on 31 pairs of ASTM standard tensile coupons of Al 6063 alloy as a commonly used food grade metal for aluminum equipment, cookware and utensils were conducted. UTS test results of an unexposed (control) coupon pair and 31 pairs of coupons exposed for 60 days to the simulated environments followed by 30 days to various possible combinations of the menu samples were analyzed using relevant literature facts. The analysis indicated that the menu samples amidst the general environmental exposure conditions at the mess have negligible effects on corrosion and tensile strength of the coupons, so understandably on aluminum cookware and utensils used at the mess and health of cadets as well.

REFERENCES

[1] Mars G. Fontana. Corrosion Engineering International Edn. McGraw-Hill Book Co. 1987, pp. 50-215.
[2] Uhilig, H. H. Corrosion and Corrosion Control: An Introduction to Corrosion Science and Engineering. John Wiley and Sons Inc, 1971, pp. 70-270.
[3] T.N. Guma, Atiku Salisu Ahmed, and Abdulkareem Abdullahi Abubakar. Corrosion management and control-entrepreneurial opportunities and challenges in Nigeria, Int. Journal of Eng. R. and Applications, Vol. 7, Issue 10, (Part -6) October 2017, pp.14-23.
[4] Aluminum in contact with food | - Alumeco https://www.alumeco.com/knowledgetechnique/.../aluminum-in-the-food-industry
[5] Corrosion in the Food Industry and its Control. Benjamín Valdez Salas, Michael Schorr Wiener, Margarita Stoytcheva, Roumen Zlatev and Monica Carrillo Beltran In: Food Industrial Processes-Methods and Equipment, Edited by: Benjamin Valdez, In-Tech Publication, February 2012 pp. 262-371.
[6] Technical Document Guidelines on Metals and Alloys used as Food Contact Materials. Council of Europe's Policy Statements Concerning Materials and Articles intended to Come into Contact with Foodstuffs Policy Statement Concerning Metals and Alloys-13 02 2002.
[7] Food Contact Materials-metals and alloys Nordic guidance for authorities, industry and trade. Nordic Council of Ministers 2015, Hanne Lebech , Denmark.
[8] Comprehensive List of Food-Safe Metals for Sheet Metal & Wire Forms. https://www.marlinwire.com/blog/food-safe-metals-for-sheet-metal-wire-forms
[9] Foods Standard Agency. Guidance on Legal Compliance and Best Practice for Business Documentation Materials and Articles in Contact with Food, September 2008.
[10] What are the pros and cons of aluminum versus stainless steel?-Quora https://www.quora.com/What-are-the-pros-and-cons-of-aluminum-versus-stainless-steel.
[11] Risk Assessment Studies Report No. 35, Chemical Hazard Evaluation Aluminum in Food May 2009, Centre For Food Safety, Food and Environmental Hygiene Department. The Government of the Hong Kong Special Administrative Region.
[12] Essam A. H. Al Zubaidy, Fathia. S. Mohammad and Ghada Bassioni. Effect of pH, salinity and temperature on aluminum cookware leaching during food preparation. International Journal of Electrochemical Science, 6(2011), pp. 6424-6441.
[13] Stephanie Ellis. Knowledge about Corrosion Prevention Crucial for Success in Food Manufacturing Industry. Mon, 05/18/2015. https://www.foodmanufacturing.com/.../knowledge-about-corrosion-prevention-cruci....
[14] H.J. Gitelman [1989]. Aluminum and Health, a critical review, Marcel Dekker, Inc.
[15] ASTM G1-03. Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens. ASTM West Conshekon Pa USA, 2003.
[16] Jahleel, A. Durami. Assessment of Alkaline Food Environment Corrosion with some Menus at NDA Cadets' Mess on the Tensile Strength of Aluminum 6063 Alloy. A research project submitted to the Department of Mechanical Engineering, Nigerian Defence Academy, Kaduna, in partial fulfillment of the requirement for award of the Degree of Bachelor of Engineering in Mechanical Engineering, June 2018.
[17] Sulaiman, I.Y; Oloche, O.B; and Yaro, S.A. (2013).The Development of a Mathematical Model for the Prediction of Corrosion Rate Behaviour for Mild Steel in 0.5M Sulphuric Acid. Extracted from ISRN Corrosion volume 2013 (2013) Article ID710579. http://dx.doc.org.10.1155/2013/710579.
[18] Corrosion of Aluminum and Aluminum Alloys (#06787G), Chapter 1, Introduction. Edited by: J.R. Davis, ASM International, 1999.



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