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# Investigating the Corrosion Behaviour of Different Metals in Raphia Fibre Extract

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**ABSTRACT:** Wood pulp and paper production is a viable aspect of the manufacturing/industrial sector which could create opportunities for employment and enhance national economic growth. Unfortunately, approximately 98% of paper and paper products currently being consumed in Nigeria are grossly import goods to the country quantified as over 50 billion Naira investment trade-away. Meanwhile, there are abundant forest and wood materials that are suitable for production of paper and associated products in Nigeria which are completely neglected at the moment. Preliminary investigation that led to this study revealed that previous attempts for utilizing these abundant wood materials have been challenged by the corrosion effects reported with some wood-pulp together with its impacts on processing vessels and techno-economic difficulties such occurrence presents on profitability and efficiency of the entire paper production value chain. Little is known about individual behaviour of some selected wood extracts in Nigeria and the corrosion impacts of each organic component contained in the cooking liquor. Hence, designing efficient processing technique in order to limit the electrochemical effects on various metal materials as well as developing appropriate corrosion inhibition methods to combat the challenge have not been trivial.

This study examined the corrosion behaviour of mild steel and stainless steel materials in the pulp produced from one of Nigeria's palm trunk that is abundantly available and suitable for paper production. Corrosion behaviour of the steel coupons were investigated in raphia wood chips that is cooked in solutions of NaOH, Na<sub>2</sub>S, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> and Na<sub>2</sub>SO<sub>4</sub> under varied pulp concentrations and different temperatures. The results obtained showed that the pulp has a higher corrosion effects on mild steel than stainless steel. A progressive thinner surface width observed on both mild state and stainless steel showed that changes in the materials depends largely on the concentration of dissolving acid while the trend in weight loss measurement with temperature showed that corrosion rate increases with increase in temperature of the medium especially on the sides closer to the bottom of the digesting vessel which is closer to the source of heat supply. Linear correlation exists between this observation and the effect of temperature on weight loss in the general experiment.

**KEYWORDS:** Raphia Pulp, metals, Corrosion effects, Socio-economic values

### I. INTRODUCTION

Pulp and paper industry is an important area to consider for national economic growth as well as opportunities for employment and wealth. This is because paper and paper products are integral part of human daily life. Even with the advancement of digital technology and modern computing system, one cannot really do without the use paper and / paper products. For instance, studies revealed that over 500 million newspapers are printed and read daily across the world and approximately 95% of business information in each nation are initially stored on paper before uploading them into computer system/database [1, 2]. In related development, the activities of the paper industries published by the American Forest & paper Association (AF&PA) revealed that in 1998 alone, the United States paper and allied products industry recorded a total sale of \$164.9 billion with \$3.6 billion in earnings [3]. More than ten years after, the sector has grown to more than double especially in Africa considering the global population growth and its effects on

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paper requirements. Presently in South Africa, approximately 0.6% was added to the country's Gross Domestic Product (GDP) by the pulp and paper sector in 2014 alone while the sector currently employs over 150,000 people within the entire paper making value chain across the country [4].

However, contrary to the huge success already recorded over the last two decades in this sector across world, nearly all paper products currently being consumed in Nigeria are still grossly import goods to the country with over 50 billion Naira spent annually on paper importation [5]. Meanwhile, Nigeria is blessed with rich and sizeable land resources which could be of immense benefits to the country. The total land area of the country is about 92, 376, 800ha comprising (91,076, 800ha of land) and (1, 300, 000 ha of water) [6]. Out of this, approximately 33% (30, 050, 000ha) is arable, 3.1% (2, 823, 500ha) is under permanent crop, 44% (40, 073, 729 ha) under permanent pasture, 12% (10, 929, 216ha) is under forest and woodland and approximately 0.3% (282, 000ha) is under irrigation [7]. The various agriculture practices in Nigeria constitute approximately 84,108, 445ha of the total land area including forest, wood and tree plantations from which pulp could be hydrolysed to produce cellulosic fibre and paper products [7]. These available wood materials and forest residues have the potential to provide means of livelihood for thousands of unemployed youths and serve as a means of foreign exchange for the country if well harnessed and effectively managed.

Raphia palm (*raphia hookeri*) is a tropical wine palm that is widely distributed in south eastern and south southern parts of Nigeria. The socio-economic benefits of raphia palm have been reported by several authors [8, 9, 10] and its importance as potential source of medicinal extracts has also been well documented [11]. Badmus et al, [12] claimed that the mid-rib of raphia leave as well as the trunk are useful items for domestic furniture and various art works. Other raphia parts have also found uses in production ornaments and native jugs in Akwa Ibom state of Nigeria. However, despite the aforementioned attributes and potentials, raphia tree dies immediately after tapping it to obtain the palm sap (wine) which is further processed to various useful products leaving the resultant trunk and biomass to rot and decay. The magnitude of raphia palm residues currently lying waste within these areas calls for their utilization in value-add to raphia cultivation. Most especially as Nigeria currently considers commercial production of papers and allied products. It is worth noting that several attempts have been made to increase the number of useful products from raphia palm. Notable area in such attempts is investigating the sustainability of raphia trunk and petiole as source of medium length fibre for pulp and paper production. Odeyemi [13] and Oviasogie [9] confirmed that raphia fibre length of about 1.57m compares well with those of Birch, Maple, Eucalyptus and Binetina which are about 1.2m, 0.8m, 1.0m and 1.1m respectively. However, just like the case with several other wood pulp, a great challenge confronting large-scale adoption of raphia dissolved cellulose materials as feedstock in commercial paper production has to do with the strong corrosion effects of the pulp on machine parts and other processing equipment [14]. In order to enhance the competitive edge and increase economic viability of the crop even after useful extracts had been obtained, the current study considers an in-depth investigation on the corrosion properties of raphia fibre and its effects on different steel materials under various process conditions. It is the authors opinion that proper knowledge and documentation of the corrosion profile will enhance development of improved processing methods and appropriate inhibition techniques that will circumvent the constraints.

## II. MATERIALS AND METHODS

### Location of study and raphia collection

The experiment was conducted at the Nigerian Institute for Oil-palm Research (NIFOR), main station in Benin City, Edo State Nigeria. Raphia tree used for this study were sourced from a swamp area in south-eastern part of Nigeria with geographical coordinate of 4° 42' N to 6° 54' N Latitude and 5° 33' E to 7° 38' E Longitude. The annual rainfall for the location averaged between 1,600mm to 2,500mm with approximately 70% relative humidity and annual mean temperature of 28°C. A number of criteria were considered for selecting this location among several options of locations with high presence of raphia palms. Details and procedure of the selection criteria is not within the scope of this presentation and issue relation to such will be addressed in subsequent review.

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## Collection and preparation of materials

This study employs the weight loss techniques to measure the corrosion effects of raphia pulp on mild steel and stainless steel materials. Several samples of medium length raphia wood discs were obtained from felled raphia palm tree after full extraction of the palm sap. The wood discs were dried and reduced to chips of varied smaller sizes (about 0.8cm minimum) to simulate an industrial wood/log crusher. Mild steel and stainless steel used for the weight loss study were provided by the Engineering Research Division, NIFOR and used as supplied. The steel coupons were analysed for elemental compositions using optical emission spectrophotometer as presented in table 1. The steel materials were smooth-cut to reduce the size and then machined using centre lathe for ease of clamping during immersion. Just before the experiment, the machined steel coupons were degreased and washed using acetone and distilled water respectively and their various initial weights were taken before exposure to raphia pulp. Other steel materials yet to be used were air-dried and stored in 2 separate desiccators each for different type of metals.

## Preparation of chemicals and reagents

Solutions of NaOH, Na<sub>2</sub>S, Na<sub>2</sub>SO<sub>4</sub> and Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> were prepared as the cooking liquor and make chemicals under standard condition following ASTM procedure. There concentrations in the pulp at different batches of experiment are presented in table 2. Due to unavailability of self-owned facilities as at the time of this experiment, commercial grade acetone and distilled water were used as supplied.

The wood chips were digested in separate stainless and mild steel heating vessels using 12% solution of the cooking liquor. The wood materials were cooked for 6 hours per batch and maintained at different temperatures. In order to avoid complications of experimental results, stainless steel vessel was used for digesting the pulp in which stainless steel coupons were exposed to while the heating vessel used for mild steel coupons was made of mild steel materials.

**Table 1: Chemical composition and analysis of different samples of mild steel and stainless steel (% Wt)**

Material	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Fe
MS <sub>i</sub>	0.200	0.006	0.180	0.031	0.050	0.062	0.090	0.103	0.056	Bal
MS <sub>j</sub>	0.204	0.004	0.181	0.030	0.051	0.062	0.086	0.105	0.053	Bal
SS <sub>i</sub>	0.050	0.482	1.629	0.029	0.009	17.200	9.262	0.420	0.335	Bal
SS <sub>j</sub>	0.053	0.501	1.621	0.027	0.012	17.010	9.200	0.480	0.341	Bal

The steel coupons were completely immersed in raphia pulp under varying temperatures as well as pulp concentrations to investigate the effects of these conditions on the corrosion of both mild steel and stainless steel.

The rate of corrosion was evaluated using equation 1 as described by [15].

$$R_{cr} = K \Delta W \rho A T \quad \dots\dots\dots \text{Equation 1}$$

Where K is the corrosion rate constant  $8.76 * 10^4$ , ΔW is the percentage weight loss, ρ is the density of metal, T is the period (time) of exposure and A is the calculated area. The effects of cooking liquor concentration on the corrosion of the steel samples was also observed and evaluated by quantifying the potentiodynamic polarization of the metals in varied pulp concentration at constant temperature.

**Table 2: Composition of in-organic chemicals at different batches**

	NaOH (g/L)	Na <sub>2</sub> S (g/L)	Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> (g/L)	Na <sub>2</sub> SO <sub>4</sub> (g/L)	Percentage solids
B <sub>1</sub>	18.00	9.64	5.63	0.25	16.38
B <sub>2</sub>	20.65	8.29	4.51	0.35	16.47
B <sub>3</sub>	18.92	7.97	4.73	0.24	15.18
B <sub>4</sub>	20.50	8.45	8.25	0.45	15.57
B <sub>5</sub>	18.86	10.28	7.35	0.28	15.36
B <sub>6</sub>	16.75	10.74	7.61	0.35	14.47

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### III. RESULTS AND DISCUSSION

The gradual changes in formation and properties of mild steel and stainless steel coupons when immersed in raphia pulp had been studied at varied temperatures and at different concentration of chemicals in the pulp. The results from different observations for mild steel samples are presented in figure 1 and 2 while that of stainless steel are shown in figure 3 and 4. Mild discoloration was first noticed on both types of steel material during the course of study. This was first observed with the mild steel coupons after about 20days of immersion before the same reaction became apparent on stainless steel samples around the 30<sup>th</sup> day of immersion. This may not be unconnected to the reduction of ionic sulphur species as well as electrolytic formation of polysulphides and trisulphides.

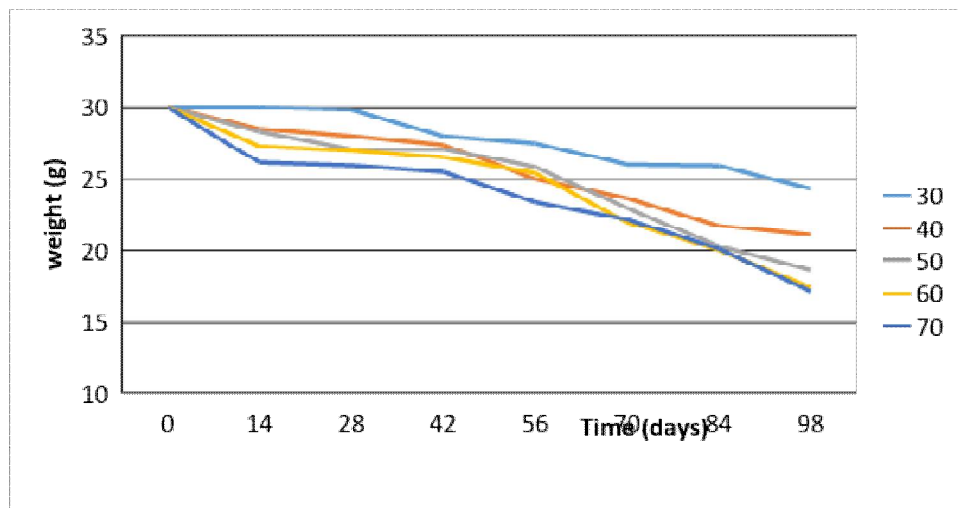


Figure 1: Weight loss of Mild steel coupons with time at different temperature (30<sup>o</sup> to 70<sup>o</sup> C)

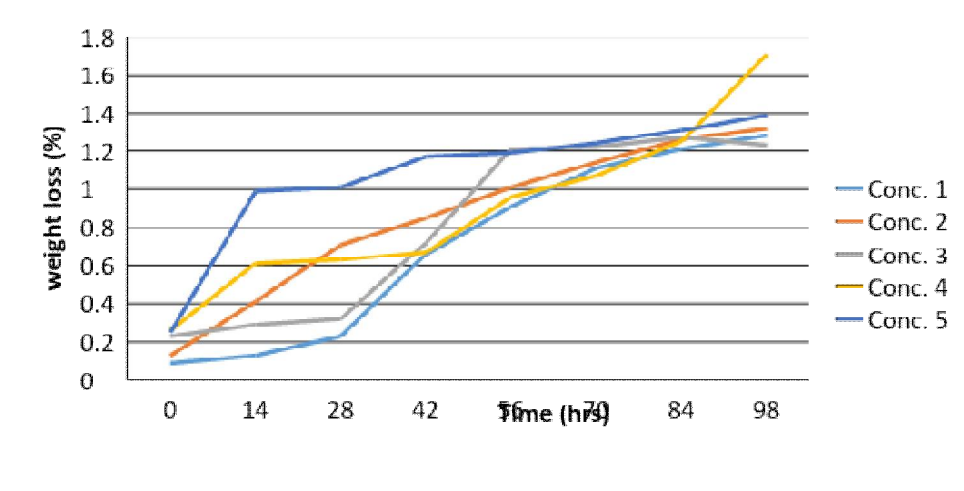


Figure 2: Mild steel weight loss variation at different concentrations of cooking liquor solution

There was progressive reduction in weight on the two types of steel materials considered as reaction proceeds but the effect was more pronounced in the mild steel coupons compared to the stainless steel. After about 60days, the deep ends in both steel coupons appeared to be more corroded than the end closer to the surface of the pulp with minor cracks on the mild steel samples towards the base of the heating vessel. While observed corrosion and / discoloration

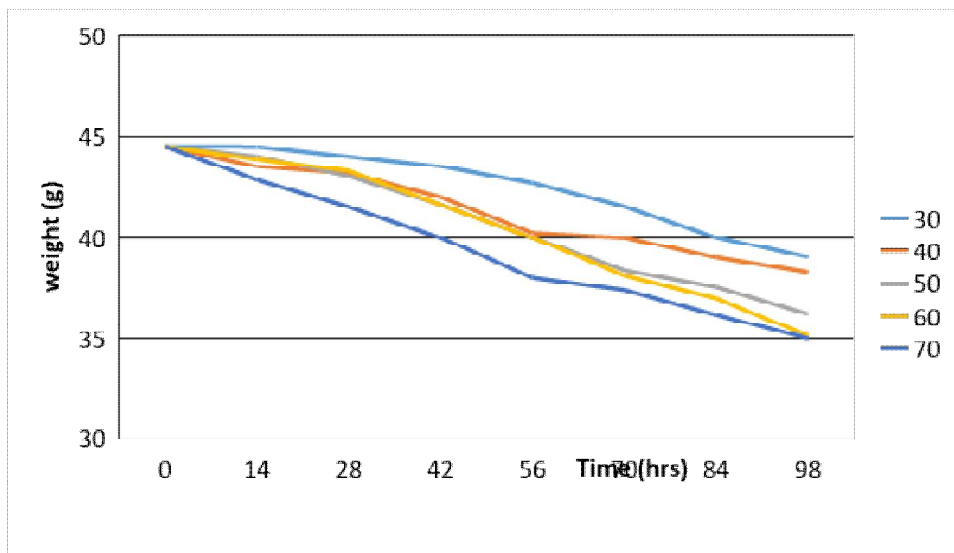
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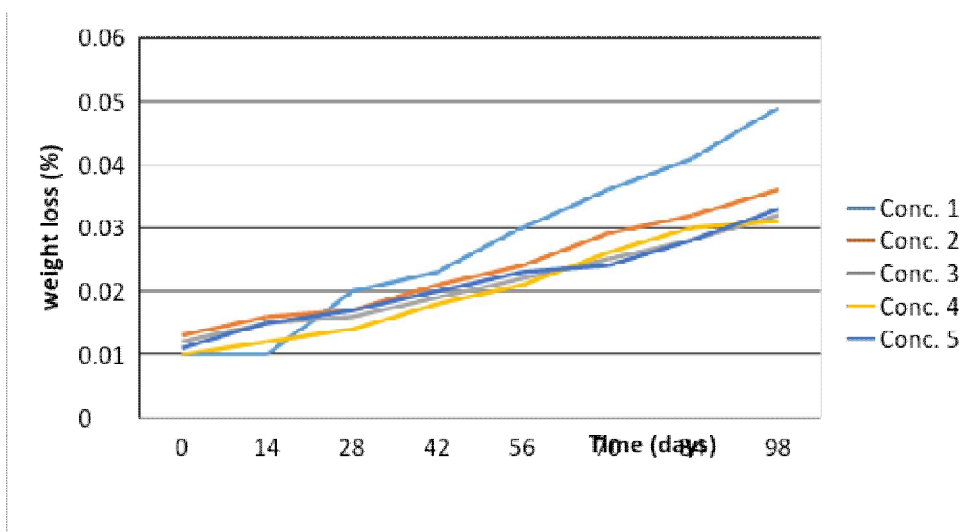
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was uniform on the stainless steel with less severe attack on the structure of the exposed part of the stainless material. The cracks on the mild steel appeared to have occurred along the path of initial discolouration and started with the vessels that are controlled at 60°C and 70°C towards the base nearer to heat source. These observations demonstrate that corrosion of metals depends largely on the rate of diffusion of ions via the thin films of the sulphide formed within the process. The results also show that temperature of the medium as well as mechanical and geometrical dynamics of the process also tends to stimulate the rate of corrosion and material deterioration. Observations during the experiment also showed that weight loss for the two steel materials increased with time and concentration. This could be attributed to several previous established claims that rate of chemical reaction increases with time and concentration.



**Figure 3: Weight loss of Stainless steel coupons with time at different temperature (30<sup>o</sup> to 70<sup>o</sup> C)**



**Figure 4: Stainless steel weight loss variation at different concentrations of cooking liquor solution**

The effects of corrosion were more significant and higher on mild steel coupons while uniform and less severe attack was seen on the stainless steel. This may not be unconnected to high percentage of Cr and Ni in the stainless-steel material as shown in table 1. According to Sharma et al. [16] and Sharma et al. [17], Cr serves as a guard that prevents

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corrosion by forming  $\text{Cr}(\text{OH})_3$  at higher pH whereas Mo may not be considered for corrosion inhibition since it dissolves as  $\text{MoO}_4^{2-}$  within the same reaction pH [18]. However, since progressive increase in the concentration of thin film and was observed on the stainless-steel materials during the course of study, relations between variations in pulp and chemical concentrations and its effects on residual elements in stainless steel material require more investigation in order to establish material formulation/combination for optimal corrosion resistance.

## IV. CONCLUSION

The corrosion behaviour of mild steel and stainless steel coupons in the pulp of raphia has been investigated using the weight loss technique. Significant resistance to corrosion had been found with tested samples of stainless material. However, the increase in temperature and concentration of the cooking liquor also show gradual weakness in the strength of stainless steel. In order to limit this reaction, further and detail study is recommended on the effects of long term immersion and increased concentration on the structure of the residual elements present in different stainless steel materials. Furthermore, since corrosion rate increases with increase in temperature, it is also recommended that important trade-off between concentration of the cooking liquor and temperature be determined for optimal pulp production. The behaviour of different steel materials in other cooking liquor used for producing wood pulp is also recommended. It is the authors opinion that present study provides useful insight on the behaviour of mild steel and stainless steel materials in raphia pulp. It is believed that this knowledge will be useful for developing relevant pulp processing techniques and appropriate corrosion methods.

## V. ACKNOWLEDGEMENTS

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