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Comparative Characterization of Soaps Prepared from Plant-sourced Alkali Solutions and Caustic Soda

Osabohien, Emmanuel[1]; Diagboya, Paul N.[2]

[1]Department of Chemical Sciences, University of Delta, Agbor, Delta State, Nigeria
[2]Environmental Fate of Chemicals and Remediation (EnFaCRe) Laboratory, University of Delta, Agbor, Delta State, Nigeria

Abstract

One of the basic ingredients of modern soap making is synthetic alkali such as caustic soda or lye (NaOH). The utilization of plant-based alkalis to make soap has been compared to the use of synthetic caustic alkalis (sodium hydroxide). Synthetic alkalis cause significant adverse effects on the environment which may be drastically reduced by using plant-based alkalis. Nigeria is an agrarian economy ranked among the first five largest producers of both plantain (*Musa paradisiaca*) and oil palm (*Elaeis guineensis*) in the world, thus generating large amounts of wastes from both plants. Hence, to reduce these wastes and effluents from synthetic alkali, improve environmental aesthetics, and create a new economy, plant-based alkalis were produced from the ashes of unripe plantain peels (UPP) and oil palm bunches (OPB) and used for soap making and the as-prepared soap were compared to soap from synthetic caustic soda. Alkali and soap properties such as alkali strength, mineral contents, soap solubility, soap pH and conductivity, lathering, moisture contents, and bulk density of the soaps were compared. Results showed that UPP had higher ash content than the OPB, though both ashes contained high mineral contents especially for Na and K. The UPP had slightly higher soap pH and conductivity than the OPB. Soap from the synthetic caustic soda (SCS) lathered more than both the biomass-based soaps in both distilled and hard water, though the biomass-based soaps have better solubility compared to the SCS soap. The textures of the biomass-based soaps were slightly softer than the SCS soap, and the bulk density of the UPP was far higher than those of the OPB and the SCS. The pH values of both plant-based soaps were higher than the SCS pH as well as the usual pH values of soaps to be used for skin wash (pH 8 to 10) and thus should not be used as skin wash as it is likely to irritate the human skin. The soaps may be used for laundry, dish washing, and other cleaning purposes.

Keywords: Soap; Plant-based alkali; Plantain peels; Oil palm bunches; Caustic soda.

Website: http://ujsti.unidel.edu.ng

DOI:

Corresponding Author: emmanuel.osabohien@unidel.edu.ng

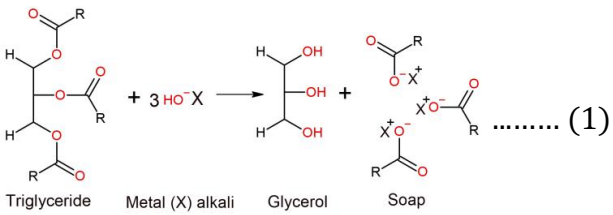
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1.0 INTRODUCTION

The high-dependence of the soap industry on synthetic chemicals has significant effects on the environment because of the enormous discharge of chemical effluents into the environment (Mohubedu, Diagboya, Abasi, Dikio, and Mtunzi, 2019). One of the basic ingredients of soap making is alkali such as caustic soda or lye (NaOH) (Olabanji, Oluyemi, and Ajayi, 2012). In the soap making process, caustic soda is involved in the saponification process which is the hydrolysis of fats or oils to produce metal carboxylate (which is the soap) and glycerol as the usual byproduct (Eq. 1)(Waithaka and Muriuki, 2019).

Effluents from soap making using synthetic chemicals can increase the pH of the environment because of the high amount of alkali it contains (Olabanji *et al.*, 2012; Waithaka and Muriuki, 2019). In order to reduce the environmental effects of the discharged synthetic alkalis from soap

making, alkalis could be sourced natural materials such as biomass. Several reports have shown that natural alkalis could be sourced from various plant ashes (Olabanji *et al*., 2012; Taiwo, Oluwadare, Shobo, and Amolegbe, 2008; Waithaka and Muriuki,



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2019). Naturally sourced alkalis have advantages which include improvement of environmental aesthetics by reducing and reusing waste and harmful pollution, making soap readily available to the consumers, reduction in the cost of soap, growing the local economy, and providing employment.

Nigeria is a significant agrarian economy that produces high amount of biomass as waste. Some of the biomasses from this economy include those from plantain (*Musa paradisiaca*) and oil palm tree (*Elaeis guineensis*). Nigeria is among the first five largest producers of both plantain in the world (Akinyemi, Aiyelaagbe, and Akyeampong, 2008; Olumba and Onunka, 2020) and oil palm (USDA, 2024). Thus, significant amounts of wastes are generated from these crops. In order to reduce the amounts of wastes produced from these crops, improve environmental aesthetics, reduce effluents from synthetic soap chemicals, and create new economy from these wastes, the objective of this study was to compare soaps produced from plant-based alkalis obtained from unripe plantain peels (UPP) and oil palm bunches (OPB) ashes and that from synthetic caustic soda.

2.0 MATERIALS AND METHODS

2.1 Chemicals, biomass sourcing and pretreatment, and soaps preparation

Analytical-grade reagents and deionized water were used during this study. The reagents include sodium hydroxide (NaOH), magnesium sulphate ($MgSO_4$), sodium chloride (NaCl), and hydrochloric acid (HCl). Unripe plantain peels (UPP) and defruited oil palm bunches (OPB) were obtained from local farms in Delta State, Nigeria. These were thoroughly washed with tap water to remove sand and dirt before sun drying for about 7 d. The biomasses were oven dried (separately) for 6 hours at 110 °C and calcined in air to ashes at ≈550 °C for 3 h. The ashes were carefully collected and stored before alkali extraction. Approximately 100 g of the ash was soaked in 500 mL distilled water for 3 days to extract the alkali content. This was filtered using Whatman® No. 1 filter paper before re-extracting the ash residue with 250 mL of distilled water twice, the extracts were pulled, and heated to reduce the water content to ≈500 mL. The alkali extracts from the unripe plantain peels and defruited oil palm bunches were labeled properly, and employed in the saponification process.

Preparation of the soap involved measuring three sets of about 200 mL of palm oil into stainless steel containers which were heated to 60 °C. Three types of soap were prepared depending on the source of the alkali: UPP, OPB, or laboratory caustic soda (SCS). The specific alkali solution (≈250 mL) was added slowly over 1 h to the heated oil while stirring, and then 50 mL of NaCl (20 %) solution was added to salt out. The soap was allowed to cool slightly before pouring into the mould to take shape.

2.2 Characterization of the soaps

Comparative characterization of the chemical-based and plant-based alkali soaps was carried by determining the alkali strength (in molarity), soap solubility, soap pH and conductivity, lathering, moisture contents, emulsifying ability, and bulk density of the soaps. The molarity of the alkalis was tested by titrating 10 mL of the alkali against a 0.1 M HCl solution (Olabanji *et al*., 2012). The soap solubility test was carried by dissolving 2 g each of the as-prepared soap in 20 mL of distilled water in 50 mL polyethylene centrifuge (Falcon™) tubes which were agitated end-to-end at 200 rpm for 10 min. The pH and conductivity

were determined by dissolving 20 g of the as-prepared soap in 50 mL of distilled water and the pH of the soap solution was measured with a calibrated pH meter (Olabanji *et al.*, 2012) and subsequently with a conductivity meter. The lathering test was carried by dissolving 2 g each of the as-prepared soap in two sets of duplicate 30 mL water of varying hardness in 50 mL Falcon™ tubes: pure distilled water and 2 % MgSO4 water (hard water). The tubes were capped tightly and agitated end-to-end at 200 rpm for 30 min and the heights of the lather immediately after stopping the agitation and 5 min after were measured (Taiwo *et al.*, 2008). The moisture content was determined by drying 10 g (w1) of the as-prepared soap to constant weight (w2) at 105 °C, and then calculating the percentage moisture content (MC %) from Eq. 2 (Onyango, Oyaro, Osano, Mesopirr, and Omwoyo, 2014). The emulsifying ability was tested by adding 3 drops of palm oil into centrifuge tubes with 30 mL of distilled water which were then added 2 g of the as-prepared soap and agitated for 20 min at 200 rpm. Metals contents in the biomass were determined using flame atomic adsorption spectroscopy (AAS) (F-AAS, Shimadzu AA-7000, Japan) after digesting 10 g of the biomass in aqua-regia. The bulk density (g/cm3) of the as-prepared soap was determined by recording the volume (cm3) of water displaced by 10 g of the soap (Olu-Owolabi, Diagboya, and Ebaddan, 2012) and calculating the specific gravity using Eq. 3.

$$MC\% = \frac{(w_1 - w_2)}{w_1} \times 100 \quad \text{.....(2)}$$

$$GS = \frac{weight}{volume} \quad \text{.....(3)}$$

3.0 RESULTS AND DISCUSSION

Some characteristics of the dried UPP and OPB biomasses are presented in Table 1. The mineral content of the biomasses were high especially for the soap making minerals: Na and K. Similar high mineral contents have been reported in plantain biomass especially for Fe (Olabanji *et al.*, 2012). It was observed that the UPP biomass had higher percentage ash content than the OPB biomass at the calcination temperature of 550 °C. This suggested that any soap prepared from UPP ash may exhibit a higher alkali content and thus higher soap pH than that from the OPB ash. This was confirmed by determining the pH of the prepared soaps from both ashes which showed that the UPP soap had a slightly higher pH than the OPB soap (Table 1). The pH values of soaps in this study are higher than the usual pH values of soaps to be used for skin wash (pH 8 to 10) and thus should not be used as skin wash as it is likely to irritate the human skin (Narayana *et al.*, 2024). In agreement with the pH values, the UPP soap also expressed higher conductivity than the OPB soap. The results of lathering test are presented in Table 2. Overall, it was observed that the SCS soap lathered more than both the biomass-based soaps in both distilled and hard water. The lower lathering of the biomass-based soaps may be due to the presence of impurities in the extracted alkali solutions such as ions of Ca, Mg, and Fe (Table 1) which cause hardness in water (Onyegbado, Iyagba, and Offor, 2002). However, comparing both biomass-based soaps, there were no significant differences in their lathering abilities. Comparing the lather heights after 5 min, it was observed that the SCS soap lost approximately 33% of its height in distilled water while the biomass-based soaps lost approximately 55% of their heights. Interestingly, a reversal in trend was observed in hard water where the loss value was 40% for the SCS but 20% for both biomass-based soaps. This suggests that the stability of the lather from biomass-based soaps is more consistent than lather from laboratory-based alkali soap. The solubility of the various soaps shows that the biomass-based soaps have better solubility compared to the SCS soap. It is believed that this higher solubility may not be unconnected to the high levels of mineral ions in these biomasses (Table 1).

Comparatively, the textures of the biomass-based soaps were slightly different (softer) from the SCS soap (harder), and this textural difference may be the result of the presence of several mineral impurities including Mg, Ca and Fe ions. Similar trend has been reported in literature for biomass-based soaps (Taiwo *et al*., 2008). The bulk density of the UPP was far higher than those of the OPB and the SCS, and this may not be unconnected to the high amount of total fatty matter (TFM) in plantain biomass (Taiwo *et al.,* 2008).

Table 1. Some properties of the UPP and OPB dry biomasses and soaps

Property	UPP	OPB	SCS
K (mg/kg)	5001.1	6100.0	-
Na (mg/kg)	984.0	142.0	-
Mg (mg/kg)	9141.8	13400.0	-
Ca (mg/kg)	1680.4	1803.0	-
Fe (mg/kg)	267.0	394.0	-
Weight of dry biomass (g)	4320	5426	-
Ash content at 550 °C (g)	765	894	-
Ash content at 550 °C (%)	17.7	16.5	-
Soap moisture content (%) at 105 °C	6.8	6.0	-
Concentration of alkali solution (mol/dm^3)	0.98	1.20	-
pH of alkali solution	9.4	10.2	-
pH of soap	11.9	11.5	11.0
Conductivity (µS/cm)	7007	5910	6100
Bulk Density (g/cm^3)	1.5	0.9	1.0
Solubility (g/100 mL water) at 30 °C	10.8	11.0	3.9

Table 2. Average lathering strengths (in cm) of the SCS, UPP and OPB soaps

Soap	Distilled water		Hardwater	
	0 min	5 min	0 min	5 min
SCS (in cm)	6.0	4.0	2.0	1.2
UPP (in cm)	4.0	1.8	1.0	0.8
OPB (in cm)	4.0	1.9	1.0	0.8

For their emulsifying abilities, the plant-based soaps were able to effectively disperse the 3 drops of oil into the distilled water after 20 min of agitation, indicating that both soaps were good emulsifying agents. However, the soaps moisture contents were below the recommended range of between 10 -14 % (Table 1). Moisture content is used in assessing the soap's shelf life; higher content could lead to hydrolysis of soap on storage or reaction of unsaponified fats with excess water to give glycerol and free fatty acid (Onyango *et al.,* 2014).

CONCLUSION

Synthetic alkali such as caustic soda or lye (NaOH) is one of the basic ingredients of modern soap making but its high-dependence has significant effects on the environment. This could be drastically reduced by sourcing alkali from plant biomass. Nigeria is a significant agrarian economy, and produces significant waste biomass. To reduce these wastes and effluents from synthetic alkali, improve environmental aesthetics, and create a new economy, plant-based alkalis were produced from ashes of unripe plantain peels (UPP) and oil palm bunches (OPB) and used for soap making.

The UPP had higher ash content than OPB, while both ashes contained high mineral contents especially for Na and K. The UPP had slightly higher soap pH and conductivity than the OPB. Soap from the laboratory caustic soda (SCS) lathered more than both the biomass-based soaps in both distilled and hard water, but there were no significant differences in the lathering abilities of UPP and OPB. However, the biomass-based soaps have better solubility compared to the SCS soap. The textures of the biomass-based soaps were slightly softer than the SCS soap. The bulk density of the UPP was far higher than those of the OPB and the SCS. The pH values of both plant-based soaps were higher than the usual pH values of soaps to be used for skin wash (pH 8 to 10) and thus should not be used as skin wash as it is likely to irritate the human skin. The soaps can be used for laundry, dish washing, and other cleaning purposes.

Naturally sourced alkalis have advantages which include improvement of environmental aesthetics by reducing and reusing waste and harmful pollution, making soap readily available to the consumers, reduction in the cost of soap, growing the local economy, and providing employment.

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CONFLICT OF INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

AUTHOR'S CONTRIBUTIONS

Osabohien, Emmanuel: Conceptualization, Investigation, Methodology, Formal analysis, Validation, Funding acquisition, Resources, Supervision, Project administration.

Diagboya, Paul N.: Writing-original draft/ review & editing, Funding acquisition, Data curation, Formal analysis, Resources

REFERENCES

Akinyemi, S.O.S., Aiyelaagbe, I.O.O, and Akyeampong, E. (2008). *Plantain (Musa spp.) cultivation in Nigeria: a review of its production, marketing and research in the last two decades.* Paper presented at the IV International Symposium on Banana: International Conference on Banana and Plantain in Africa: Harnessing International 879.

Mohubedu, R.P., Diagboya, P.N.E., Abasi, C.Y., Dikio, E.D. and Mtunzi, F. (2019). Magnetic valorization of biomass and biochar of a typical plant nuisance for toxic metals contaminated water treatment. *Journal of Cleaner Production, 209*, 1016-1024. doi: 10.1016/j.jclepro.2018.10.215

Narayana, A.V., Sumalatha, B., Babu, D.J., Venkateswarulu, T.C., Chandrasekhar, K., Rashmik, I. and Chandrika, V. (2024). Synthesis, Preparation, and Characterization of Natural Soaps from Some Selected Plant Extracts. *Journal of Biochemical Technology,* 15(**1-2024**), 6-11.

Olabanji, I.O., Oluyemi, E.A. & Ajayi, O.S. (2012). Metal analyses of ash derived alkalis from banana and plantain peels (Musa spp.) in soap making. *African Journal of Biotechnology,* 11(**99**), 16512-16518.

Olumba, C.C. and Onunka, C.N. (2020). Banana and plantain in West Africa: Production and marketing. *African Journal of Food, Agriculture, Nutrition and Development,* 20(**2**), 15474-15489.

Olu-Owolabi, B.I., Diagboya, P.N. and Ebaddan, W.C. (2012). Mechanism of Pb2+ removal from aqueous solution using a nonliving moss biomass. *Chemical Engineering Journal, 195-196*, 270-275. doi:10.1016/j.cej.2012.05.004

Onyango, V.P, Oyaro, N., Osano, A., Mesopirr, L. and Omwoyo, W.N. (2014). Assessment of the physicochemical properties of selected commercial soaps manufactured and sold in Kenya.

Onyegbado, C.O., Iyagba, E.T. and Offor, O.J. (2002). Solid soap production using plantain peel ash as source of alkali. *Journal of Applied Sciences and Environmental Management,* 6(**1**), 73-77.

Taiwo, A.A., Oluwadare, I., Shobo, A.O. and Amolegbe, S.A. (2008). Extraction and potential application of caustic potash from kolanut husk, ugwu pod husk and plantain peels. *Scientific Research and Essay,* 3(**10**), 515-517.

USDA. (2024). Production-Palm Oil. Retrieved May 11, 2024

Waithaka, P.N. and Muriuki, J.N. (2019). Preparation of Soap Using Banana Peel and Olive Tree Ashes. *Animal Science Journal,* 10(**1**), 22-29.