



Production of Detergent from Rice Husk Sodium Silicate

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Abstract Rice Husk as waste materials in the rice industry is rich in silicate with about 90% compositions. The purpose of this research is to convert this agro-waste to rice husk ash (RHA) from which sodium silicate is extracted and used for detergent production. The RHA was obtained by burning rice husk in a muffle furnace at a temperature of 700°C for 6 hours. Thus, 130g of the rice husk was charged in the furnace at the mentioned temperature and the weight at an hour interval was 58.20g at 1hr, 56.42g at 2hrs, 54.75g at 3hrs, 53.90g at 4hrs, 53.40g at 5hrs and 52.70g at 6hrs. The RHA obtained was reacted with Sodium hydroxide (NaOH) solution of 1M and 2M concentrations at different temperatures of 30°C, 60°C and 100°C to produce Sodium silicate. The volume of the Sodium silicate obtained at the various temperatures was 44.7mL, 40.3mL and 36.4mL for 1M NaOH, and 45.6mL, 41.8mL and 38.7mL for 2M NaOH solution. The quality analysis of the produced Sodium silicate at the different concentrations of NaOH compared to industrial Sodium silicate resulted in the following; pH value: 12.46, 13.09 and 12.35, viscosity: 28.68, 26.89 and 25.47Pa.s and alkali determination: 0.0627, 0.0794 and 0.0730. Additionally, the solubility test showed that it was soluble in water and insoluble in alcohol. Furthermore, the detergent samples produced from the different Sodium silicate from RHA (i.e. sodium silicate from 1M NaOH and sodium silicate from 2M NaOH) and industrially made sodium silicate was analysed for its quality parameters and the results obtained were foam stability of 43, 55 and 80 minutes, free alkali content of 0.0830, 0.0629 and 0.0741, pH value of 10.14, 10.21 and 10.38, and moisture content of 9, 7 and 11% for 1M NaOH, 2M NaOH and industrial Sodium silicate, respectively. Therefore, the use of high concentration of NaOH and completely ashed rice husk will result in a better Sodium silicate quality for detergent production.

Keywords Rice husk, Rice husk ash, Sodium silicate, Detergent

1. Introduction

The first industrially made cleaning detergents occurred in the First World War era when the German economy was in distress and left them without easy access to soap. In 1930, commercially available methods for making fatty alcohols brought the rise of general brands intended for industrial use [1]. After the Second World War, several American war effort factories were changed for citizen use and one of the most widely available products was tetra propylene. These products were used to produce homemade detergents. In the 1930s and 1940s, soap was almost completely faced out as a means of cleaning clothes in developed countries. One of the most popular detergents then was alkylbenzenesulphonates, but its inability to be biodegradable forced the manufacturers to create linear alkylbenzenesulphonates, which were more degradable.

Another compound – Sodium triphosphate, which comprises about 50% by weight of detergents, was in use. However, a profound problem arose from the excess use of the compound. The disposal of soluble phosphates into natural waters, that is, streams and lakes, resulted in problems with eutrophication or the growth of living organisms in water bodies. According to Barlass [2], the substitute for Sodium triphosphate by Zeolites offers some relief to the problems associated with Sodium triphosphate. The most important and largest application of detergents is for washing clothes (laundry purposes). This reflects the high demand and application of this



product which results in a highly competitive consumer market [3]. This demand arises as a result of the qualities of detergent which is dependent on how it is being produced, the various qualities and quantities of components used for the detergent production.

Nowadays, with the increased use of phosphates in the absence of species feeding on algae, algal blooms grow wonderfully from the excess phosphorus to produce toxins that can kill dolphins, fishes, and plants. These organisms can indirectly cause oxygen depletion at deeper depths, through a microbial breakdown of dead algal cells. Hence, recent laundry detergents do not contain phosphates but bring about water softening using zeolites [2]. Science and technology are currently undergoing research that will bring remedies to the effects of these chemicals in detergents and one of such ways is the use of agricultural products which is considered to be more environmentally friendly [4]. It is on this note that the motivation of this work comes out.

In rice-producing regions, disposal of rice husk is frequently a major challenge which is often addressed by indiscriminate dumping and pile burning, which contributes to global warming and health issues. This raises the need for the utilization of rice husk (which is considered as waste) for the production of sodium silicate. In most varieties, rice is made up of about 20 % of rice husk. This husk contains fibrous materials and silica which compositions hinge on the geographic location and climate of rice plant. Hence, because of the high grain content (about 80%) of rice, the husk is considered a by-product in the mills which creates disposal and pollution problems. Rice husk is high in ash that contains about 92 to 95% silica. This rice husk ash (RHA) is light weighted and greatly porous with high external surface area. Its absorbent and insulating potentials are useful in several industrial applications. For instance, it is use as strengthening agent in building materials. Mansaray and Ghaly [5] mentioned that rice husk a major by-product of the rice milling industry and one of the most commonly available lignocellulosic materials that can be converted to different types of fuels and chemical feedstocks through a variety of thermochemical conversion processes.

Currently, many industries burn rice husk as an alternative fuel to generate energy; which is a useful solution, regrettably, this results in a new waste, called rice husk ash (RHA). This ash obtained from the combustion process contains over 60% of silica and some quantity of metallic impurities [6]. Contingent upon the burning route, RHA can contain silica in the amorphous form; this ash can be considered as a new economically viable raw material to produce silica or to be used as silica resource (<https://eduprojecttopics.com>). Sodium silicate solutions are also known as “sodium water-glass” are complex mixtures of polymer silicate particles and silicate anions, especially when silica module ($\text{SiO}_2:\text{Na}_2\text{O}$ molar ratio) is higher than two [7]. Sodium silicates production process is considered expensive because of the energy required to attain the calcination stages temperature. Other factors that add to the high cost of sodium silicate production are air pollution from emission of dust, nitrogen and Sulphur oxides. Although the calcination process is normally used in the industry, there is another method that is based on the reaction of silica with sodium hydroxide (NaOH) solution in an autoclave. This latter process has an advantage over the conventional calcination approach as it requires less energy – temperature. Therefore, in this study, the silica content in RHA will be utilized by reacting with sodium hydroxide to form Sodium silicate for the production of detergent.

1.1. Sodium Silicate

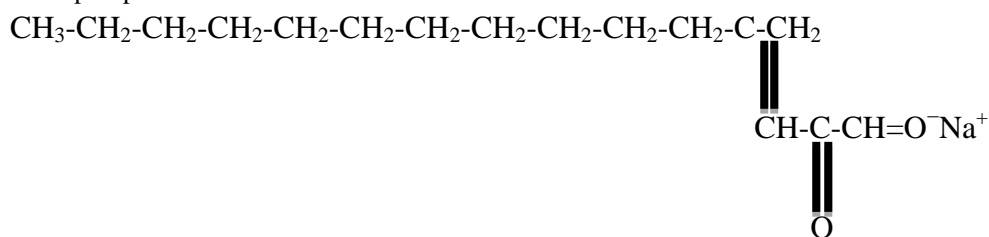
Compounds with the general formula $\text{Na}_2(\text{SiO}_2)_n\text{O}$ is Sodium silicates. In this series, the well-known member is sodium metasilicate with the molecular formula Na_2SiO_3 . These materials are available in aqueous solution and solid form. The unalloyed compositions are white while commercial samples are mostly greenish or blue due to the presence of iron-containing impurities. Sodium silicate, usually known as ‘water glass’ or ‘liquid glass’, is popular in the industry due to its wide commercial applications. In 1640, van Helmont discovered Sodium silicate as a fluid substance by melting sand in excess alkali. Another chemist, Von Fuchs in 1825, obtained what is now referred to as water glass by treating silicic acid with an alkali and the product being soluble in water. Again, Von Wagner differentiated the types of a water glass as potash, soda, double (potash and soda) and fixing. Generally, Sodium silicate – white powder, dissolution in water gives an alkaline solution. Just like other related compounds, namely, sodium pyro silicate, sodium ortho-silicate, among others, are glassy, colourless and soluble in water. Silicate ion reacts with hydrogen ions in acidic medium to produce silicic acid, and when heated; it forms silica gel which is glassy substance. According to American Chemical Society (2003), other



properties are, appearance: white to greenish opaque crystal, density: 2.61g/cm^3 , melting point: $1,088^\circ\text{C}$, solubility: in water and not in alcohol, and refractive index: 1.52 [8].

1.2. Detergent

Detergent is a water-soluble cleaning agent that combines both impurities and dirt to make them soluble, unlike soap; its variant is not forming a scum with salts in hard water. Often we use the words soap and detergents interchangeably, but they are two different things. Barlass [2] mentioned that detergents are chemical substances that break up and remove grime and grease in the same matter as soap but remain efficient even in hard water. In hard water, soap form insoluble compounds with the magnesium and calcium ions which precipitate out and hinders the foaming and cleaning potential of soap. In contrast, detergents react with the ions in hard water to form soluble compounds or remain colloidal to be dispersed. Nowadays, detergents are synthetic chemicals mixture and additives formulated in a huge chemical plant. The use of detergent is span across from shaving foam to hair shampoo, clothes washing powder to stain removal, etc. David [10] presents the molecular structure of soap as presented below:



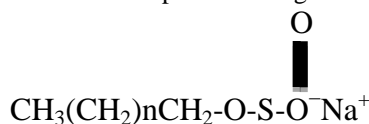
Non-polar hydrocarbon chain

(Soluble in non-polar substances)

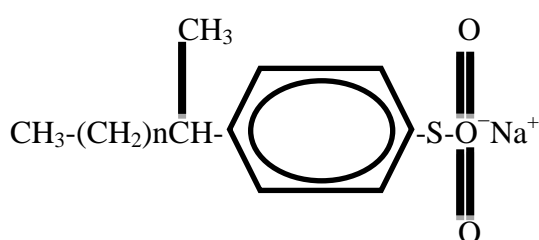
Ionic end

(Soluble in water)

On the other hand, detergents are structurally similar to soaps, but the disparity is in the water-soluble section. The two examples of detergents are shown as;



Sodium alkyl sulphate



Sodium alkylbenzenesulphonate

Detergents are amphipathic molecules that have hydrophobic and polar groups [10]. In these molecules, the polar group is at the end of the hydrophobic carbon chain. Unlike the purely polar or non-polar molecules, the amphipathic molecules show unique chemical properties in water. In water, the polar group in detergent forms hydrogen bonds with water molecules, while the hydrophobic reactions aggregate the hydrocarbon chains. These abilities allow detergents to be soluble in water. Besides, when detergent or soap is in water, their molecules clusters and it referred to as micelles. Then, the polar ends of the molecules are on the outside of the cluster, as the non-polar ends are in the middle. In aqueous forms, they form spherical structures known as micelles in which each contains numerous detergent molecules. According to Bhairi and Mohan [10], detergents



can solubilize hydrophobic compounds in water due to their amphipathic nature. Again, detergent is also known as surfactant, as a surfactant reduces the surface tension of water. Most times, the substances are alkylbenzenesulfonates – a group of compounds that are like soap but can dissolve in hard water. In these compounds, the detergent's polar sulfonate is less probable than the soap's polar carboxyl to bind with calcium and other ions in hard water [3].

2. Materials and Methods

2.1. Rice Husk Acquisition and Sample Preparation

The rice husk used in this study was obtained from a rice mill in Ikpe clan in Ini Local Government Area, AkwaIbom State, Nigeria. This material was sundried for two (2) days to reduce any moisture content. Thereafter, it was sieved to remove the rice grains content in the husk to ensure that the burning of the rice husk will not be hindered by them. Then, 130g of the rice husk was put in a crucible and placed in the electric furnace (Figure 1) at a set temperature of 700°C. After attaining the temperature of 700°C, it was allowed to stay in the furnace for 6 hours. At one hour interval, the sample was taken out using tongs to check for the ash formation and the reduction of carbon present in the rice husk ash (RHA) as the residence time increases. Afterwards, two (2) Sodium hydroxide (NaOH) solutions were prepared with 40g and 80g pellets to 1000mL (i.e., equivalent one litre) of deionized water. The solutions were allowed to ferment for 48 hours to ensure complete dissolution and mixing of the NaOH pellets.



Figure 1: Electric furnace

2.2. Production of Sodium Silicate

To produce the Sodium silicate from the rice husk ash (RHA) after pre-treatment process, ten (10) grams of RHA were reacted one mole (1M) and two moles (2M) of Sodium hydroxide (NaOH) solution in the beakers separately. These solutions were stirred thoroughly with a glass rod to ensure miscibility. They were thereafter placed in the hot air oven at a temperature of 100°C for an hour. After this, the beakers and its content were removed from the oven and pour on filter papers. The residues on the filter papers were dried at a temperature of 60°C in the oven for about 30 minutes. The viscous residues (products) on the filter papers are the Sodium silicates (Na_2SiO_3) obtained from 1M and 2M NaOH from the process. Afterwards, the Sodium silicates obtained were characterized or testing for the following properties, namely, solubility, pH value, viscosity emulsification and alkalinity.

2.3. Production of Detergent

The basic components used in the production of the detergent are presented in Table 1. Two hundred (200) millilitres (mL) of the fermented Sodium hydroxide (NaOH) solution was poured into a 1000mL beaker. Then, 10mL of the Sodium silicate (Na_2SiO_3) from 1M NaOH (Sample A) and 500mL of the palm kernel oil were added into the beaker and stirred continuously. Also, 500g of soda ash and 50g of the Sodium Tripolyphosphate (STPP) were added to the solution in the beaker while stirring was going on. Thereafter, Ammonia in proper mixing as a drying agent and Hydrogen peroxide were added to the solution and the stirring speed was increased to enhance the detergent process formation. Figure 2 shows some of the detergent production stages. As the

detergent formation process was on-going, 20mL of apple fragrance and 50g of the colour granules were added to the detergent. The formed detergent was left for 24 hours to dry out and then a sieve was used to reduce the detergent particle size to powdery form. Thereafter, the procedures were repeated to produce detergent from Sodium silicate for 2M NaOH (Sample B) and industrial Sodium silicate (Sample C). Afterwards, the properties, namely, foaming stability, stain removal ability, alkalinity value, and moisture of the produced detergents were determined.

Table 1: Component used for the detergent production

Component	Quantity
Caustic soda solution	200mL
Palm kernel oil (PKO)	500mL
Soda ash	500g
Ammonia	50mL
Hydrogen peroxide	500mL
Sodium Tripolyphosphate (STPP)	100g
Apple fragrance	20mL
Sodium silicate	10mL
Sulphonic acid	100g

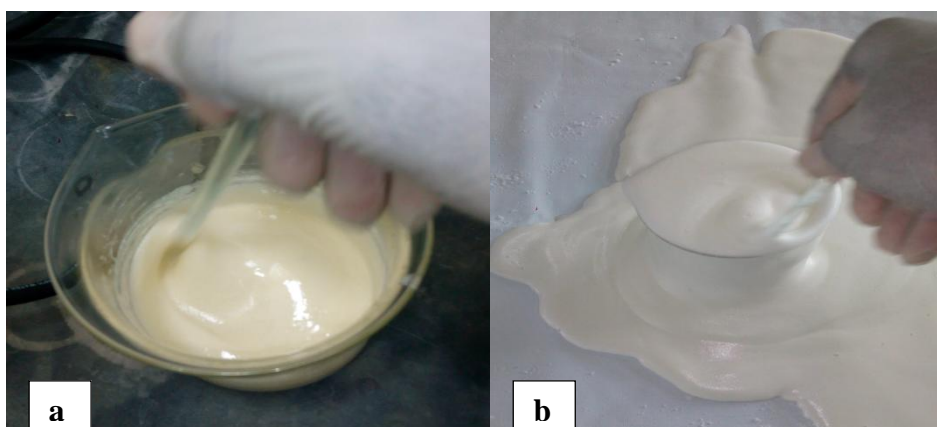


Figure 2: The detergent production process (a) shows after addition of components except Hydrogen peroxide and (b) shows foaming-out of the detergent after Hydrogen peroxide was added

2.2.1. Determination of Produced Detergent Qualities

i. Determination of Foam stability

The detergent produced was used to form lather in hard water (rainwater) and the time for the foam to collapse was determined using a stopwatch. Generally, the quality of foam produced is what makes soap or detergent different from other products. The foam produced reduces surface tension and makes it possible for cleansing to take place. Thus, foaming increases when the components of the detergent bound together effectively. Hence, foam stability is the duration with which foaming is sustained when detergent dissolves in water.

ii. Determination of pH value

pH is an important quality parameter for detergent. It is the quickest indicator that reveals the progress of a successful detergent making. It determines the friendliness or otherwise of a detergent to the skin. The quality set for detergent in terms of pH based on literature is in the range of 9 – 11. The closer the detergent is to neutrality the better the detergent quality. Thus, 1% of the detergent solution was prepared by dissolving about 0.5g of the produced detergent in 50mL of water. The heat was applied to dissolve the detergent completely. Using a pH meter the alkalinity of the solution was determined by dipping the electrode of the pH meter into the detergent solution and value obtained was recorded.



iii. Moisture content determination

This is the amount of water present in the detergent sample. Moisture affects the cleansing and lathering property of the detergent. Besides, if moisture is too low, the detergent is liable to take a long time before dissolving in water. If on the contrary, the detergent components will dissolve and lose its effectiveness in terms of foam formation and may stick to its container. A sample of the detergent (10g) was introduced into a dish and placed in an oven for 1 hour at a temperature of 80°C. It was allowed to cool and then weighed. The procedure was repeated until a constant weight was obtained and noted as the weight of the dried sample. Then, the moisture content in percentage was calculated using Equation 1.

$$M = \frac{C_o - C_d}{C_o} \times 100 \quad (1)$$

where

C_o = weight of wet sample

C_d = weight of dried sample

M = moisture content of the sample (%)

iv. Test for Free Alkali

Free alkali gives an insight into the amount of excess alkali present in the detergent. Free alkali is injurious to the skin; hence the quality of detergent is determined by how free the soap or detergent is from alkali. A sample of the produced detergent (10g) was placed in a conical flask and 100mL of neutralized alcohol (ethanol) was added. The flask and the content were placed on a water bath and heated until the detergent dissolved in the alcohol. Then, 10cm³ of Barium Chloride solution and 2 drops of phenolphthalein indicator were added to the conical flask. The whole content was titrated against 0.1M H₂SO₄ until the solution became colourless. The free alkali was calculated by;

$$A_{free} = \frac{3.1MV}{W} \times 100 \quad (2)$$

where;

M = Molarity of H₂SO₄ solution, mol.L⁻¹

V = Volume of H₂SO₄ solution used in the titration

W = Weight of the detergent sample in gram

A_{free} = Free alkali in %

3. Results and Discussion

3.1. Rice Husk Ash and Its Compositional Analysis

Figure 3 shows the rice husk ash (RHA) when it burnt for 3 hours and 6 hours in the electric furnace, while 4 presents the weight of the RHA obtained at a temperature of 700°C at each time interval. As observed, there was a decrease in the RHA weight as the time increased. Of course, this was expected as it indicates that the component, that is, the carbon content in the rice husk was burning out to ash which reduces the weight of the rice husk. The compositions of the RHA is presented in Table 2. These results were compared with some works in the literature by Rohatgi [11], Kalapathy [12], Thuadaij and Nuntiya, [13] and Basha *et al.* [14] in Table 2. From the Table, it is noted that the compositions of the RHA used in this study were comparable with the documented compositions of RHA at a temperature of 600°C. It is crystal clear that the ash obtained from the rice husk burning contains a greater amount of Silica (SiO₂) and a small number of other elements considered as impurities. The most common trace elements in RHA are sodium, potassium, calcium, magnesium, iron, copper, manganese and zinc [4].



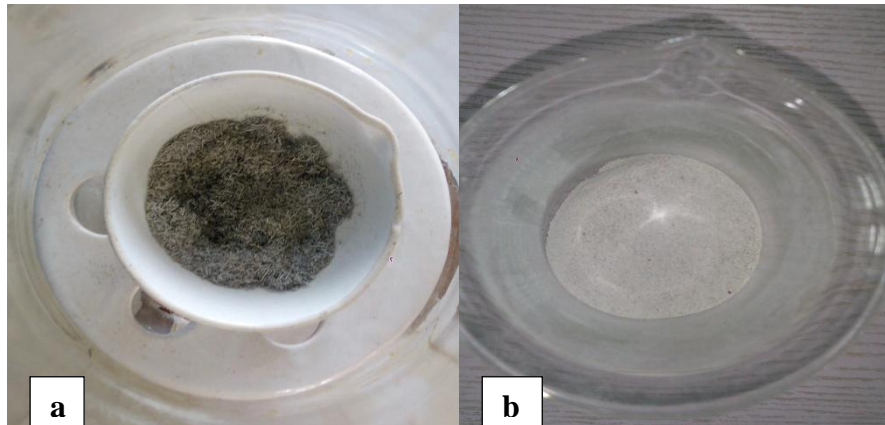


Figure 3: The rice husk ash (RHA), (a) shows incomplete ash of rice husk after 3 hours and (b) shows complete ash obtained after 6 hours

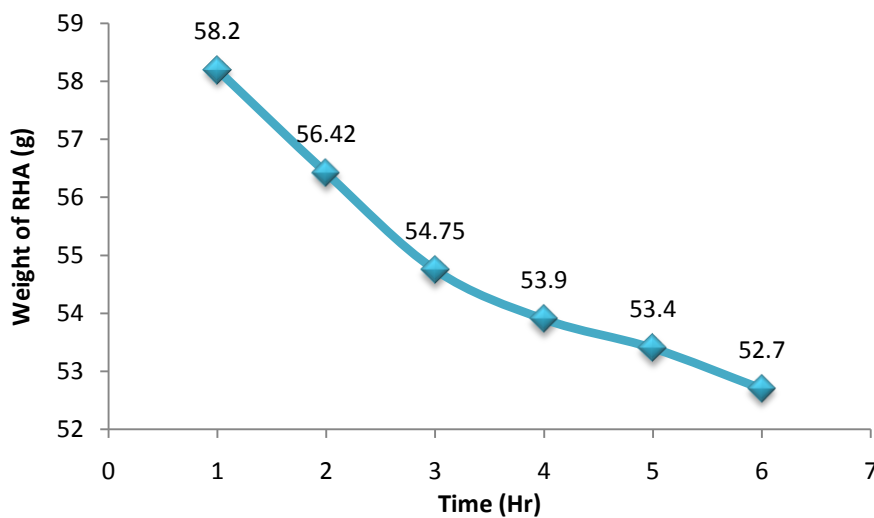


Figure 4: Weight of the RHA obtained at different time

Table 2: Chemical composition of the rice husk ash compared with some existing

Chemical Composition	% Weight from different authors				
	Rohatgi, 1989 [11]	Kalapathy, (2002) [12]	Basha <i>et al.</i> (2005) [14]	Thuadaj and Nuntiya, (2008) [13]	This study
SiO ₂	94.5	95.8	93.9	93.2	94.4
Al ₂ O ₃	0.64	0.51	0.68	0.59	0.61
K ₂ O	0.86	1.32	0.79	1.28	1.06
Na ₂ O	0.79	0.76	0.83	0.68	0.77
MnO	0.61	0.62	0.56	0.58	0.56
CaO	0.81	0.85	0.91	0.76	0.83
MgO	1.18	1.17	1.23	1.27	1.21
Fe ₂ O	0.045	0.043	0.051	0.037	0.045
Others	0.46	0.53	0.56	0.50	0.52

3.2. Formulated Sodium Silicate and Properties

The most abundant element in RHA is Silicate (SiO₂) as noted in Table 2. From the chemical reaction between the RHA’s Silicate (SiO₂) and Sodium Hydroxide (NaOH) result in the formation of Sodium silicate (Na₂SiO₃) and water (H₂O); as represented in Equation 3. Table 3 presents the volume of Sodium silicate produced at different temperature and mole concentration of NaOH. It is observed that the volume of Sodium Silicate (Na₂SiO₃) produced a decrease as the temperature increases. This means the temperature is used for the breaking of the chemical bonds of Silicate compound from other elements which may be considered as impurities in the

RHA. Besides, there was a slight increase in the volume of Sodium silicate (Na₂SiO₃) produced at 2M NaOH than 1M NaOH. The use of 2M NaOH solution produces a more viscous Sodium silicate (Na₂SiO₃) compared than the use of 1M NaOH.



Table 3: Sodium silicate volume produce at varied temperature

	Conc. of NaOH	Temp. (°C)	Sodium Silicate Vol. (mL)
i.	1M NaOH	30	44.70
		60	40.30
		100	36.40
ii.	2M NaOH	30	45.60
		60	41.80
		100	38.70

The solubility test of the formulated Sodium silicate (Na₂SiO₃) from RHA and industrial Sodium silicate (Na₂SiO₃) in water and 95%w/w alcohol showed that the industrial Sodium silicate (Na₂SiO₃) was soluble in water and insoluble in alcohol. RHA Sodium silicate (Na₂SiO₃) was incompletely soluble in both medium, it gave cloudy colour with the homogenous mixture. The cloudy colour was attributed to the presence of other elements in the RHA. Figure 5 presents the pH values obtained from the RHA Sodium silicates (Na₂SiO₃), that is, samples A and B, and industrial Sodium silicate (Na₂SiO₃) (Sample C). The pH value from 1M NaOH RHA Sodium silicate (Na₂SiO₃) was close to the industrial Sodium silicate (Na₂SiO₃), while 2M NaOH RHA Sodium silicate (Na₂SiO₃) was slightly higher. For viscosity, the RHA Sodium silicates (Na₂SiO₃) were relatively higher than the industrial Sodium silicate (Na₂SiO₃) (Figure 6). Comparison of the RHA Sodium silicates (Na₂SiO₃) shows that 1M NaOH Silicate was higher than 2M NaOH Silicate. Again, the emulsification test indicated that the samples A through C dissolved completely in organic oil to form an emulsion (Figure 7). Sample C (industrial Na₂SiO₃) resulted in faded colour while RHA Na₂SiO₃ had cloudy colour. On the other hand, the alkalinity test results (Figure 8) showed that 2M NaOH RHA Na₂SiO₃ was higher than 1M NaOH RHA Na₂SiO₃. Also, the 2M NaOH RHA Na₂SiO₃ alkalinity value was close to the industry Na₂SiO₃ (Figure 8). Thus, 2M NaOH RHA Na₂SiO₃ was more alkaline than the other samples (i.e., A and C).

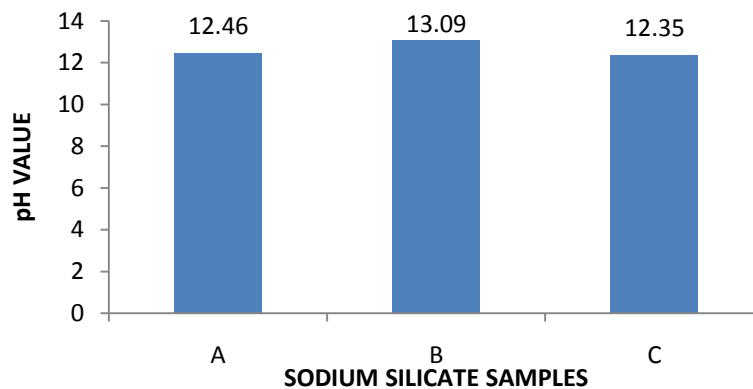


Figure 5: pH values of the Sodium silicate samples

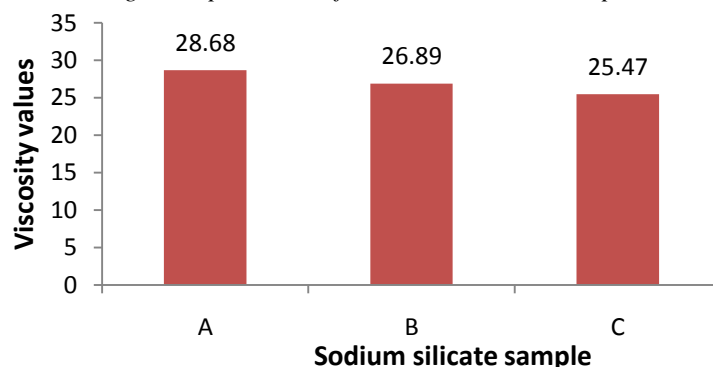


Figure 6: Viscosity values of the Sodium silicate samples



Figure 7: Formation of emulsion with sodium silicate samples

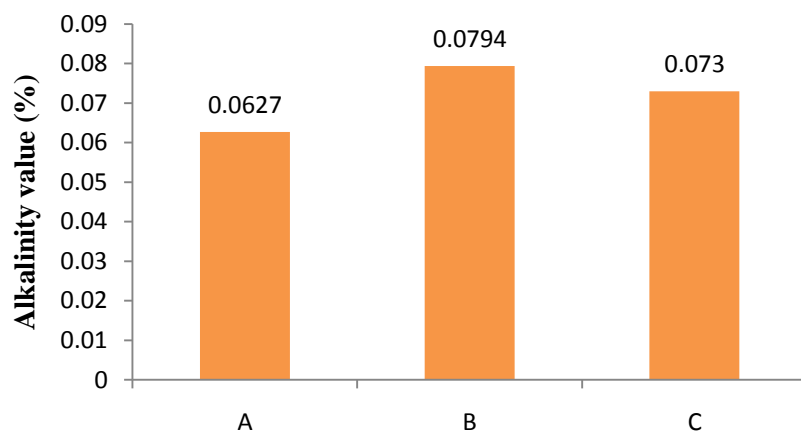


Figure 8: Alkali content of the Sodium silicate samples

3.3. Produced Detergent

Since the variance between the RHA Sodium silicates (Na_2SiO_3), that is, Samples A (Na_2SiO_3 for 1M NaOH) and B (Na_2SiO_3 from 2M NaOH), and the industrial Sodium Silicate (Na_2SiO_3) was not much, the samples were used for the production of the detergent following the general process sequence stated below. The produced detergents are presented in Figure 9.

Caustic soda → PKO → Soda ash → Sulphonic acid → Sodium silicate → STPP → Ammonia → Hydrogen Peroxide → Fragrance = DETERGENT



Figure 9: The produced detergent dried in oven



Figure 10 presents the foam stability of the various produced detergents from the Sodium silicate (Na_2SiO_3) samples. This is considered as the time it takes the detergent foam to collapse. From the Figure, it is observed that the detergent produced from industrial Sodium silicate had more satisfiable stability compared to that produced from RHA Sodium Silicate. This observation could be attributed to the inefficiency of the RHA Sodium silicate to bind the components of the detergent effectively and the presence of other elements in the RHA; as presented in Table 2. Another reason could be the incomplete dissolution of the detergent in the water.

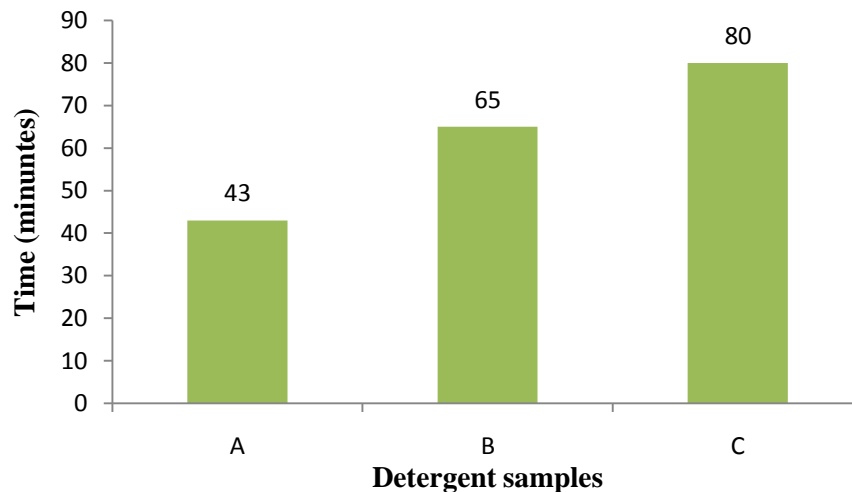


Figure 10: Produced detergents foaming stability duration

Figure 11 shows the moisture content of the produced detergents. The results obtained indicated that the produced detergent from the samples had about the same moisture content. In other words, the produced detergents from RHA Sodium Silicate and industrial Sodium Silicate have close moisture content. Also, the free alkaline and pH values of the produced detergent are presented in Table 4. It is noted that the produced detergent from the various samples (i.e., A through C) had close free alkali values. This is because the sulphonic acid used in the detergent was not sufficient or enough for the detergent to neutralize efficiently. It was observed from the result that the presence of free alkali increased as a result of the class of components used for the detergent production which could be termed as acidic. Based on the standard specifications, the allowable amount of free alkali content of detergent is of the range 0.00-0.06%. Thus, Sample B (i.e., 2M NaOH RHA Na_2SiO_3) free alkali value was more close to the standard alkali content in the literature than the other sample. This closeness of the produced detergents' free alkali is further attributed to their pH values obtained, which were within the known range of pH of 9 – 11 for quality detergent.

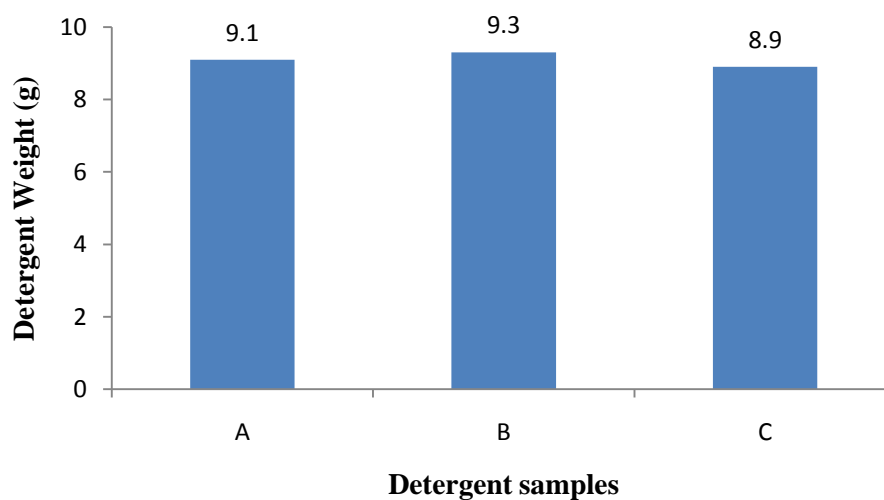


Figure 11: Moisture content of the produced detergent samples



Table 4: Produced detergents free alkali and pH values

	Sample A	Sample B	Sample C
Volume of Acid used (mL)	26.8	20.3	23.9
Free Alkali (%)	0.08308	0.06293	0.07409
pH value	10.14	10.21	10.38

In summary, industrial characteristics that are considered to be of utmost importance in the detergent production are free alkali content, pH value, foam stability and moisture content. Among these characteristics, free alkali content and pH value were observed to be affected by the quality of the basic components and the quantity of organic oil used. So far, the results obtained in respect of all these parameters indicated that the detergent was within acceptable specification and quality. Thus, the produced detergent from RHA Sodium Silicate had a comparable characteristic with the detergent from commercial or industrial Sodium Silicate; therefore, the potential of RHA Sodium Silicate should be exploited for the production of detergent.

4. Conclusion

Based on this study on the utilization of RHA Sodium Silicate for the production of detergent, the following conclusions are drawn;

- i. the RHA Sodium Silicate (Na_2SiO_3) is incompletely soluble in both water and 95% w/w alcohol, and also, its pH value is comparable with industrial Sodium Silicate (Na_2SiO_3);
- ii. again, the RHA Sodium Silicate was slightly viscous than the commercial Sodium Silicate and they both dissolve in organic oil to form an emulsion;
- iii. the produced detergent from RHA Sodium Silicate properties, namely, foam stability, free alkali, pH value, etc. were comparable with detergent produced from commercial Sodium Silicate.

It is recommended that further work should look at an effective approach to pre-treat the RHA to remove other elements which may act as impurities in the formation of Sodium Silicate.

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