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Research Article

Characterization of Kaolin-rich Laterite Soil for Applications for the Development of Soil-based Cosmetic Products

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Abstract

The present study aims to characterize the properties of the raw and thermally activated laterite soil to be used to develop cosmetic products. Collected soil samples were washed and air-dried for 48 hours, collected soil samples were air-dried for 48 hours. Air-dried soil was crushed to create 500 µm powdered materials. Thermally activated soil samples were prepared by heating the laterite soil at 100 ^{0}C, 200 ^{0}C, 300 ^{0}C, and 400 ^{0}C for 3 hours in a muffle furnace. The physicochemical properties of laterite such as morphology, surface functional groups, elemental composition, surface area, and trace elements were analyzed. The Cell Forming Unit (CFU) was counted in the raw soil, and thermally activated soil samples at the beginning. Antimicrobial Assay was tested with *Candida albicans, Pseudomonas aeruginosa, Staphylococcus aureus* microorganisms in raw and thermally activated laterite soil. An uncountable amount of microorganisms per gram was observed in the raw soil sample and fewer microorganisms were counted in 100 ^{0}C, and 200 ^{0}C samples. The CFU was zero microorganisms per gram for the 300 ^{0}C, and 400 ^{0}C samples. The optimum density of the culture is measured to estimate the growth of the microbial cells. Oil absorption, sweat absorption and swelling capacity were used to characterize the samples with raw and thermally activated soils. The characterization results indicated that chosen soil samples have good oil and sweat absorption, good swelling capacity and microbiological safety, making them suitable for cosmetic applications.

Keywords: Cosmetics, Chemical analysis, Laterite soil, Microbiology, Thermally activation, physiochemical features

1. INTRODUCTION

Clays are ample, low-cost, and environmentally friendly resources that have a wide range of applications in various fields of trade [1]. Clay minerals are a remarkable exception because their synthesis is hard and costly. In contrast, such natural minerals as calcite, halite, or gypsum are used because they are abundant and low-priced. Since ancient times, common clays have been used in cosmetics and health applications [2]. Even nowadays, clay minerals (kaolin, mica, talc, smectite, vermiculite) and non-silicate minerals (calcite, halite) as active elements in pharmaceutical and cosmetic formulations are practiced [2, 3].

The scientific measures for choosing clay raw materials for a particular technological application depend on the degree of pureness and the properties of the clay minerals present, described as mineral composition, size, particle distribution, reactivity, catalytic activity, specific surface area, swelling capacity, and cation exchange capacity. Other necessities must also be fulfilled to escape potential risks to human health for applications in the health field, such as active principles, adsorbents, fillers, and excipients in pharmaceutical and cosmetic formulations. In these cases, stability, chemical inertness, low or null toxicity, and safe microbiological activity should be according to the limit advised in the international Pharmacopoeia Standards [4, 5] even as good adsorptive capacity, pleasant colors, neutral colors, neutral colors, odor, softness, and appropriate rheological properties [6].

The main clay minerals used in the pharmaceutical and cosmetics industry are kaolinite, talc, smectites, and fibrous clays [2]. Before use, the raw clay materials are usually benefitted using different techniques to reduce chemical impurities, advance their physicochemical properties, and increase their feature. However, the increased application of clay minerals in advanced materials raises the need for purification and enhancement.

Apart from being effective in the pharmacological or cosmetic function for which they are selected (as abrasives, absorbents, adsorbents, anticaking agents, glidants, coating agents, opacifying agents, viscosity-increasing agents, emulsion stabilizers, binders, suspending agents, therapeutic agents, tablets, and capsule diluents or lubricants), clays must also meet a number of chemical, physical, and toxicological requirements, such as steadiness, purity, chemical inertia, consistency, water content, particle size, toxicity, safety, and microbiological purity, for which specific technical specifications exist for each clay and its intended use. Since clays can be contaminated for the period of processing and storing by *Bacillus anthracis*, *Clostridium tetani*, and *Clostridium welchii*, they may be sterilized by heating at over 160 ^{0}C for at least 1 hour, or by gamma radiation exposure [7].

Clay beneficiation involves different physical and chemical treatments, such as bleaching and magnetic separation, flotation and selective flocculation, drying and calcination, size fractionation, and chemical modification and activation [8].

Common clays are generally used without any upgrading process. However, it is necessary to eradicate certain minerals, such as calcite, dolomite, quartz, feldspars, and heavy metals, surpass the pharmacopeia requirements or modify the suitable mineral properties [8] .

Size fractionation is a simple, low-cost upgrading practice that can get rid of accessory minerals and additionally lead to separating the clay into different grain-size fractions, each fraction with different chemical composition and physical properties. Thermal activation is aimed at increasing the adsorptive capacity of the soil [9, 10] . Besides, soil heating directly affects microorganisms by either killing them directly or altering their reproductive capabilities. At extremely high temperatures, soil microorganisms die because of the unfavorable temperature of the soil. Most spores formed by molds and yeasts are more sensitive to heat than bacterial spores. They are often quite resistant to heat, especially *Byssochlamys* species [11] . Therefore, thermal-activated soil should be an ideal material for additive cosmetic products [12] .

Out of the main groups of the tropical and subtropical soils of the world, the laterite soils occupy a distinctive place regarding both their wide-ranging existence and strange properties. They are widely distributed in India, Indonesia, Indo-China, Malaya, Burma, Western Australia, Madagascar, Central Africa, South America, the Guianas, Brazil, and Cuba [13, 14] . Laterite soil is red, clay-rich soil enhanced with aluminum and iron. The natural occurrence of iron and aluminum in laterite soil may open up the possibility of the potential of adsorption due to its amphoteric cation exchange capacity [15] . In addition to minerals of the aluminum and iron hydroxide groups, laterite holds significant quantities of kaolinite, filling the porous of the kaolinite-sesquioxide matrix [16] . Laterite soil contains SiO_2, Fe_2O_3, Al_2O_3, which can generate both positive and negative charges on the surface of laterite at neutral pH. This makes laterite a good adsorbent. Other than that, the high porosity and the availability of anion exchange sites are beneficial for the use of laterite as an adsorbent [17, 18] .

The present study aims to characterize the physical and chemical properties of the kaolin-rich raw and thermally activated laterite soil to be used to develop soil based cosmetic products.

2. MATERIALS AND METHODS

2.1 Materials

The laterite soil material collected from the southwestern part of Sri Lanka was washed away several times using distilled water to remove earthy impurities (sand and mud), air-dried, ground, and sieved using a 0.5 mm US standard. Different thermally activated soil samples were arranged by heating the soil at 100 ^{0}C, 200 ^{0}C, 300 ^{0}C, and 400 ^{0}C for 3 hours in a muffle furnace. After, soil samples were collected in polyethylene zip lock bags to reduce contamination.

2.2 Physiochemical analysis

2.2.1 Scanning electron microscope analyses (SEM-EDX)

The surface morphology and the structure of the prepared soil samples were obtained by scanning electron microscopy. The analysis was carried out using Hitachi S-4200 field emission SEM and double-sided conductive carbon tape of gold-sputtered soil samples mounted on the SEM sample holder. The gold sputtering of ground soil was achieved at a constant current of 25 mA [17] .

2.2.2 X-ray Fluorescence (XRF) analysis

The chemical composition of the raw laterite soil sample (RL) and 300 ^{0}C ad 400 ^{0}C thermally activated soil samples (300 AL and 400 AL) were determined by X-ray fluorescence spectrometry (RIX 2000) at the National Gem and Jewelry Research and Training Institute, Sri Lanka. Powdered samples were packed down into briquettes under a force of 200 kN for 60 s [19, 20] . The briquettes were then examined for the most important oxides and trace elements. The average error for these elements was less than±10% relative [21] **.**

2.2.3 X-ray Diffraction analyses (XRD)

The raw and 300 ^{0}C and 400 ^{0}C thermally activated laterite soils were analyzed with an X-Ray diffractometer Rigaku TTRAX III XRD instrument at the University of Sri Jayewardenepura, Sri Lanka. The powdered samples were analyzed using Cu K (alpha) radiation and wavelength (1.54 A) over 2 (theta) of 5-70^0 with a step size of 0.02^0/sec, which are relevant parameters for the clay mineral observations [22] .

2.2.4 Fourier-transform infrared spectroscopy analyses (FT-IR)

FT-IR analysis was used to identify and study the behavior of adsorption sites in raw and 300 ^{0}C and 400 ^{0}C activated soil laterite soils. The soil samples are placed directly onto the ZnSe crystal of the equipment, an FTIR Thermo Nicolet iS10, in the spectral range of 4000-400 cm^{-1}, at 16 scans, and 2 cm^{-1} resolution [17] .

2.2.5 Elution analyses to study water-soluble fraction

Since there can be accumulated metal ions readily existing in laterite soil samples, those metal ion concentrations required to be examined. Therefore, 10 g of Raw, 300 ^{0}C and 400 ^{0}C activated laterite samples were dissolved in 50 mL of distilled water, maintaining a ratio of 1:5, and were stirred for 2 hours. After 2 hours the solid phase was separated by using centrifugation (4000 rpm) for 10 min and then solutions were filtered by a millex-GP syringe filter unit pore size 0.22 µm. The filtrate was acidified using concentrated HCl for preservation and further analysis. The prepared samples were analyzed for metal ion concentrations using the ICP-MS [23] .

2.2.6 The cation exchange capacity

The cation exchange capacity (CEC) of laterite soil was determined using the $BaCl_2$ compulsive exchange method [24] . 2.00 g of the soil samples was shaken with 20 mL of 0.1 M $BaCl_2.2\ H_2O$ for 2 hrs. The solutions were centrifuged at 10,000 rpm, 5 mins, and decanted. 20 mL of 2 mM $BaCl_2.2\ H_2O$ was mixed and shaken for 1 hr. The suspensions were centrifuged at 10,000 rpm, 5 mins again and discarded the supernatant. The process was repeated twice and 10 mL of 5 mM $MgSO_4$ was mixed and shaken for 1 hr to maintain the conductivity of the solution at ~300 µS and pH within 0.1 units. Distilled water was added until the solution conductivity is that of the 1.5 mM $MgSO_4$. Finally, the treated samples were weighed and their retain nonacid cations CEC values were calculated.

2.2.7 Oil absorption capacity

The oil absorption of clay samples was measured in accordance with ASTM D281-12. A selection of clay, 1 g, was placed on a glass plate, and mineral oil (0.85 g/cm^3) from a previously weighed container was dropwise added to the clay and combined with the assistance of a spatula. The test was considered complete when a thin layer of oil was noted by sliding the spatula on the top surface of the formed mass. The oil container was weighed again to calculate the percentage of oil incorporated [23] . The absorbed amount of oil was calculated by Equation 1. Where V_1 is the initial volume of oil and V_2 is the used volume of oil. The percentage absorption was calculated according to Eq. 1.

$$\%\,Oil\ absorption = \frac{(V2 - V1)}{V1} \times 100 \qquad (Eq.\ 1)$$

2.2.8 *Swelling capacity*

The swelling capacity of the samples was measured using a process defined in Pharmacopoeias. 2 g of each sample were added portion-wise to a 100 mL graduated cylinder containing 100 mL of an aqueous solution of sodium lauryl sulfate 1%. In the period of 2 h the apparent volume of the sediment should not be lower than 22 and 24 mL, according to British Pharmacopoeia [25] , and US Pharmacopoeia [5] , respectively. The same method was followed with distilled water [23] .

2.2.9 *Artificial sweat absorption*

A sample of artificial sweat was prepared according to the ISO standard ISO 3160-2. 20 g of Sodium chloride, 17.5 g of Ammonium chloride, 4.80 mL of Acetic acid, and 13.80 mL of d,l-lactic acid were dissolved in 1 L of deionized water. The pH was adjusted to human sweat mean pH 6.3 by potassium hydroxide [26, 27] . One gram of each soil was added to the 50 mL of sweat solution. The solutions were shaken at 120 rpm for 30 minutes and filtered using a Whatman filter paper. After being treated with laterite soil samples, the titrimetric method was used to determine Lactic acid, Acetic acid, and Ammonia remaining in the artificial sweat solution. Ten milligrams of each filtrate obtained was titrated with 0.1 M NaOH using phenolphthalein as the indicator until the solution changed from clear to pink color (R_1). Then 1.0 ml of formaldehyde was added, and the titration was continued until it gave a pink color (R_2). The R_1 value corresponds to the lactic and acetic acid remaining in the solution, and $R_2 - R_1$ values correspond to the remaining Ammonia after treating with the soil [28] . The remaining soil was analyzed using FTIR to compare the samples without sweat absorbed [28] .

2.3 *Microbiological tests*

Microbiological tests of the clays were performed following methods described by pharmacopeias [5, 25] to observe the total aerobic microbial count and antibacterial effect.

2.3.1 Total aerobic microbial count

A sample of 1 g of clay (Raw laterite, 100 ^{0}C, 200 ^{0}C 300 ^{0}C or 400 ^{0}C activated laterite soil) was suspended in 10 mL of saline water, reaching the ratio of 1:10 between sample and buffer (saline water). Successive decimal dilutions of this initial suspension were prepared using the same buffer for each sample. The volume equivalent to 1 ml of clay suspension was transferred to sterilize Nutrient Agar poured Petri dish (in triplicate). After the spread of the clay solution, the Petri dishes were incubated upside down at 37 ^{0}C for 48 h. Plates containing between 30 and 300 colonies were taken into account. The colony counter was used to count the colonies. The results were expressed as the number of microorganisms per gram of sample [23] . Cell Forming Unit (CFU) was calculated using Eq. 2.

$$CFU = \frac{No\!:of\ single\ colony \times Dialution\ facor}{Volume} \qquad (Eq.2)$$

2.3.2 *Antimicrobial effect - Agar Well Diffusion Method*

Three holes (wells) were bored for the positive control, negative control, and product on the sterilized solidified nutrient agar plates. As the positive control, the commercially available antibiotic drug Amoxaline was used. A tablet of Amoxaline (500 mg) was crushed and powdered, and it was dissolved in 1000 mL of deionized water. 200 µL of each bacterial inoculum solution in log phase (*Candida albicans*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*) was transferred onto the agar plate using a micro pipette and spread evenly using a sterilized spreader. 10 µL of antibiotic solution was transferred into the first well. 0.1 mL of deionized water (negative control) was transferred into the second well. 100 mg of the soil was transferred into the third well. Then these plates were incubated for 24 hours at 37°C. After 24 hours, all the plates were examined for growth inhibition, and the diameter of each zone of inhibition was measured [29, 30] .

3. DATA AND DISCUSSION

3.1 Surface properties of Laterite soil - SEM - EDX

Laterite soil's adsorption surface has a highly porous structure with heterogeneous texture. The surface morphology of laterite soil presents flaky-shaped particles in SEM analyses (Figure 1 a, 1 b &1 c). The natural laterite is consolidated clay, which usually formed blocky structure. The EDX analyzed laterite samples are having very low contents of organic matter and inorganic carbons. The samples mainly contained aluminium, silicon and iron, which accounted for the total mass with lower abundances of trace elements (Table. 1). The results are analogous to previous studies by Vithanage et al. [31] and Dissanayake et al. [32] .

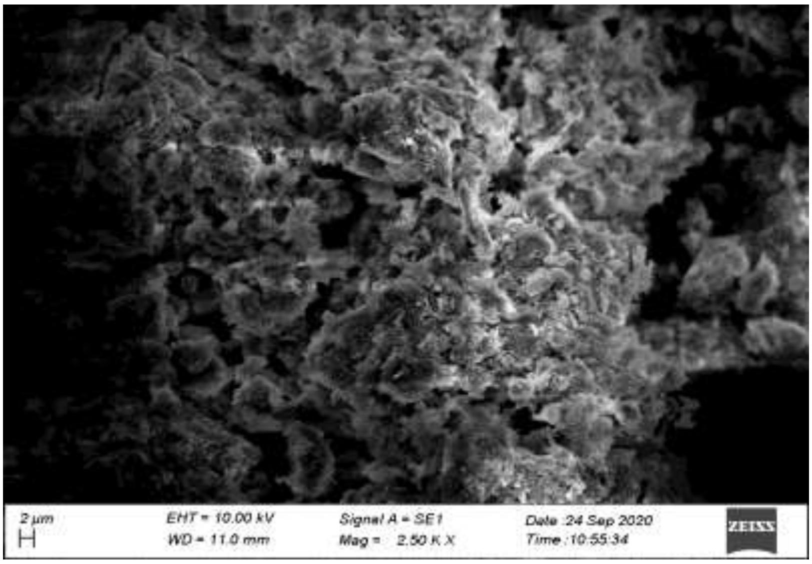

Figure 1a: SEM image of Raw Laterite

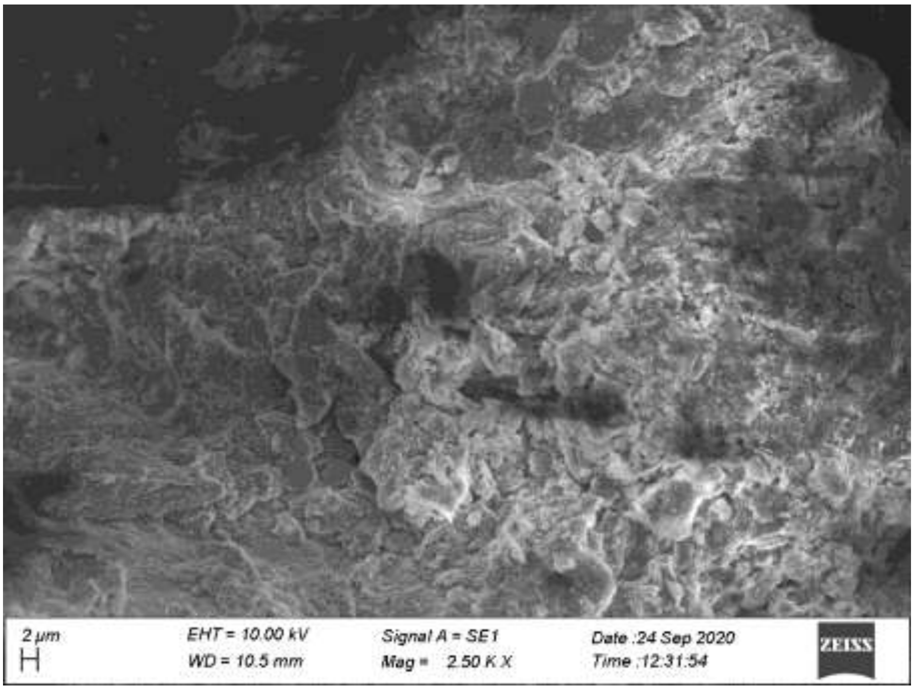

Figure 1b: SEM image of 300 ^{0}C Activated Laterite

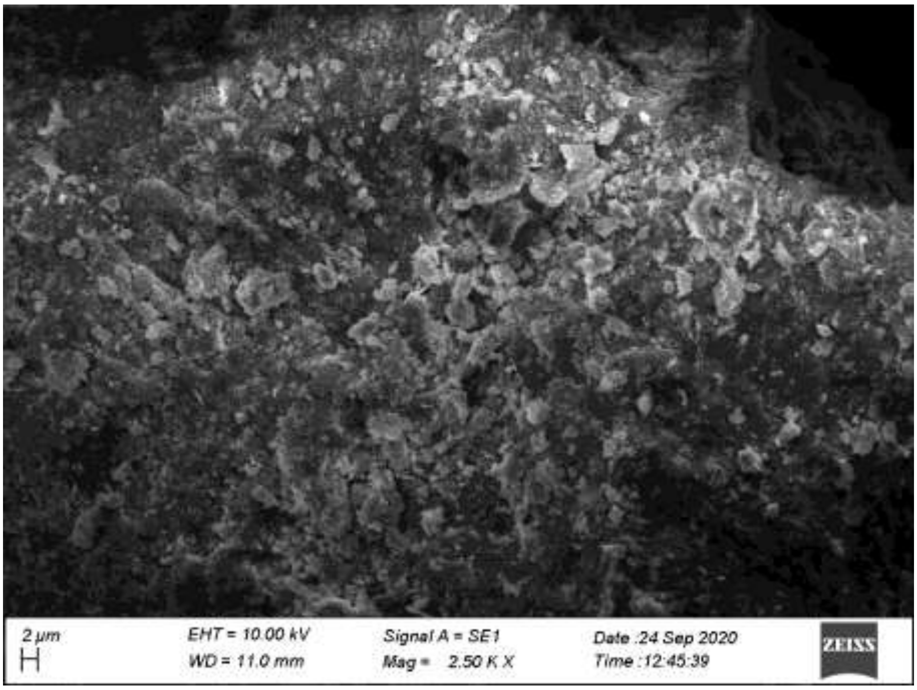

Figure 1c: SEM image of 400 ^{0}C Activated Laterite Laterite

Table 1: EDX results of Raw, 300 ^{0}C and 400 ^{0}C Activated Laterite

Element	Weight %		
	Raw Laterite	300 ^{0}C Activated Laterite	400 ^{0}C Activated Laterite
C	3.04	6.00	5.00
O	55.01	57.01	59.01
As	1.11	0.84	0.88
Al	20.32	17.56	19.56
Si	18.78	15.19	17.19
Ti	0.59	0.00	0.00
Fe	1.15	3.40	2.30

3.2 Chemical properties of Laterite soil

3.2.1 XRF analysis

The XRF analysis was performed to identify the soil composition (Table. 2). Approximately 33 elements and compounds were identified. Fe was the most common element of an average mass percentage of 65.066% in all the samples. Other than that, Al and Si were also abundant. SiO_2 was the most abundant in all three compounds. Al_2O_3 and Fe_2O_3 were also present in high amounts. Other detected compounds include TiO_2, CaO, and K_2O. The occurrence of TiO_2 in cosmetic and pharmaceutical ingredients, main anatase, is important due to their potential photocatalytic activity, which can prime to the generation of free radical and degrade inorganic ingredients used in cosmetic formulations [33]. The existence of TiO_2 in laterite soil is low amount and cannot negatively affect to human tissues.

Table 2: X-ray fluorescence results of elements and minerals in Raw Laterite (RL), 300 ⁰C and 400 ⁰C Activated Laterite (300 AL and 400 AL)

Minerals/ wt %	RL	300 AL	400 AL
SiO_2	44.6	44.3	44.8
Al_2O_3	32.9	33.5	33
Fe_2O_3	19.3	18.8	18.9
TiO_2	2.31	2.34	2.33
K_2O	0.171	0.168	0.162
CaO	0.078	0.07	0.085
Elements/ wt %			
Fe	64.8	64.6	65.8
Al	16.3	15.8	15.8
Si	14.9	15.6	14.7
Ti	1.91	1.91	1.9
Zr	1	0.98	1
Tb	0.26	0.19	0.3
Co	0.18	0.2	0.2
Gd	0.17	0.16	0
K	0.13	0.13	0.1
V	0.08	0.08	0.1

3.2.2 Heavy metal content

Heavy metals were present in minute amounts in the soil where eluted would be lower. The concentrations of As < 0.04 ppm observed for the analyzed samples are much lower than those specified by the Pharmacopoeias, limited to a maximum of 5 ppm for As (Table 3) [5, 25]. Hg and Pb were not detected.

Table 3: Other physical and chemical properties of the Raw Laterite (RL), 300 ⁰C and 400 ⁰C Activated Laterite (300 AL and 400 AL)

Sample	**Raw Laterite**	**100 ⁰C AL**	**200 ⁰C AL**	**300 ⁰C AL**	**400 ⁰C AL**
Swelling capacity in water (mL)	2	2.166	2.333	2	2
Swelling capacity in 1% - LES (mL)	24.666	24	23.666	24	24
As (ppm)	<0.04	<0.04	<0.04	<0.04	<0.04
Pb (ppm)	nd	nd	nd	nd	nd
Hg (ppm)	nd	nd	nd	nd	nd
Oil absorption (%)	96.5412	99.3882	99.6941	97.2118	96.1176

nd : Not Detected

3.2.3 XRD analysis

The XRD analyses of laterite showed the presence of clay minerals such as goethite, gibbsite, quartz, kaolinite, and hematite (Figure. 2 a & 2 b). Studies have obtained similar results for laterite in previous studies [16, 19, 32] . Geothite and gibbsite have been increased in 300 ^{0}C and 400 ^{0}C thermally activated laterite. These minerals and help raise the impurities removal properties of laterite soil by increasing ion exchange and adsorption capacity [34] .

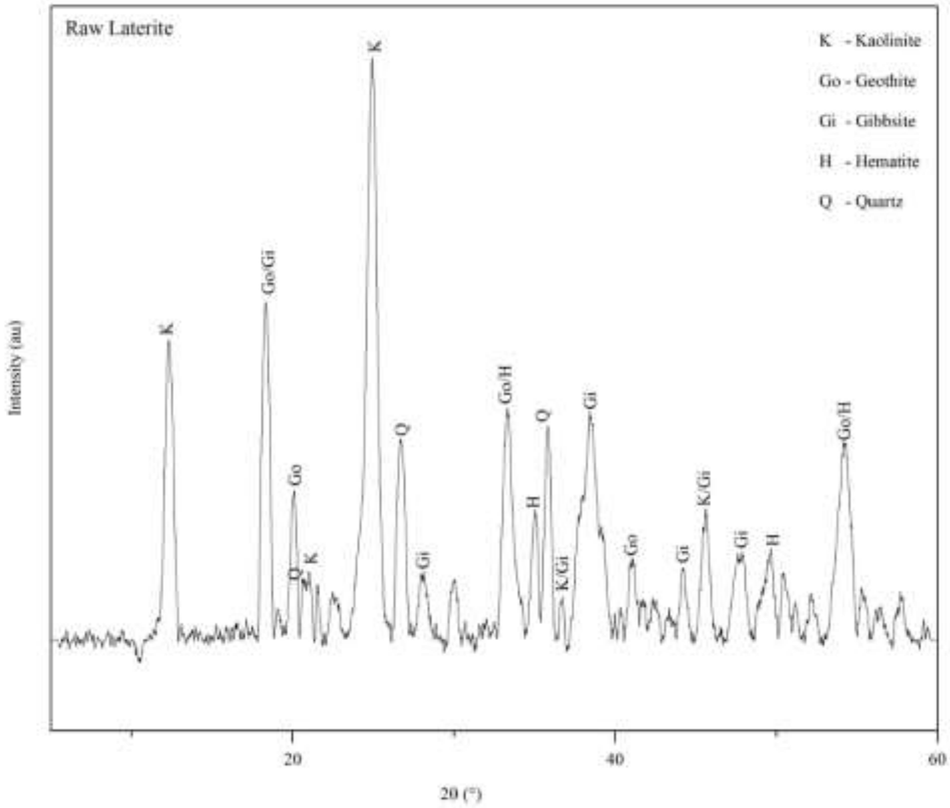

Figure 2a: XRD pattern of Raw Laterite

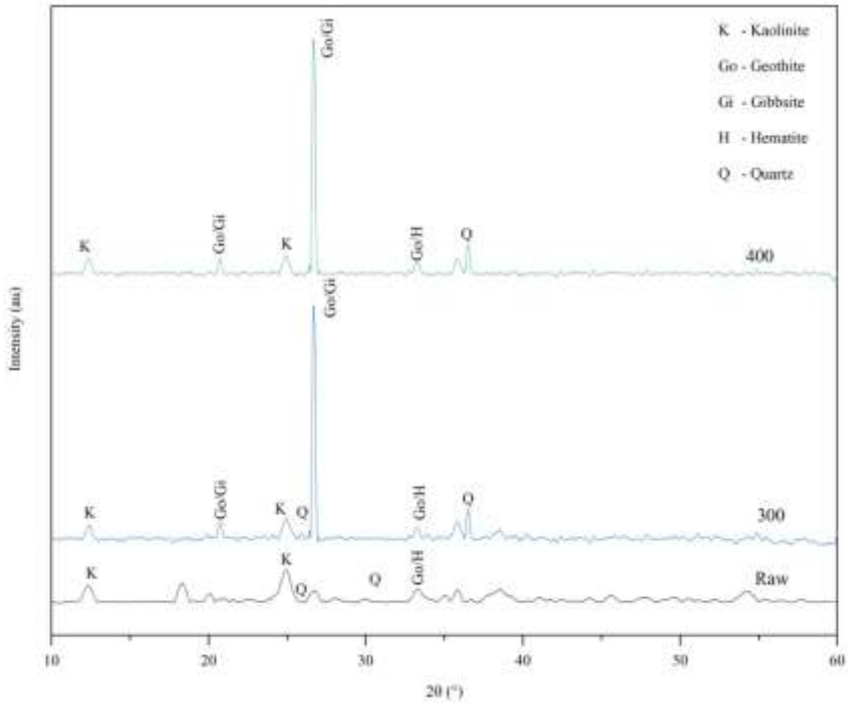

Figure 2b: XRD patterns of Raw, 300 ^{0}C and 400 ^{0}C Activated Laterite

3.2.4 FTIR analysis

In the OH stretching vibration region (3700–3300 cm⁻¹), the FTIR spectra (Figure. 3) shows three absorption bands (3688, 3619, and 3419 cm⁻¹). The stretching modes of OH bands related to free water (around 3600 cm⁻¹) and the bending mode of the H-O-H band (around 1643 cm⁻¹) were also observable (1645 cm⁻¹). The band at 3688 cm⁻¹ can be attributed to stretching vibrations of outer hydroxyl groups coordinated to iron, aluminum, or silica present in laterite [35], and the band at 3619 cm⁻¹ can be associated with inner hydroxyl groups. The absorption band near 3419 cm⁻¹ is reported by the hydroxyl bonded to trivalent cations such as Al^{3+} or Fe^{3+}. Therefore, the bands at 3419 cm⁻¹ indicate some portion of Al^{3+} or Fe^{3+} in the octahedral layer of kaolin-rich laterite. In the region of 1200–900 cm⁻¹, the bands in the region 1113, 1024, 998, and 908 cm⁻¹ are due to the presence of Si–O–Fe, Al–OH, Fe–OH vibrations bands located at 788, and 908 cm⁻¹ may be attributed to Si-O bonds linked with trivalent cations (e.g., Al^{3+}, Fe^{3+}). Thus, absorption bands at 788, and 908 cm⁻¹ indicate the occurrence of tetrahedrally molecular vibrations trivalent cations in laterite. The band at 541cm⁻¹ signifies the presence of Fe–O bond stretching [17].

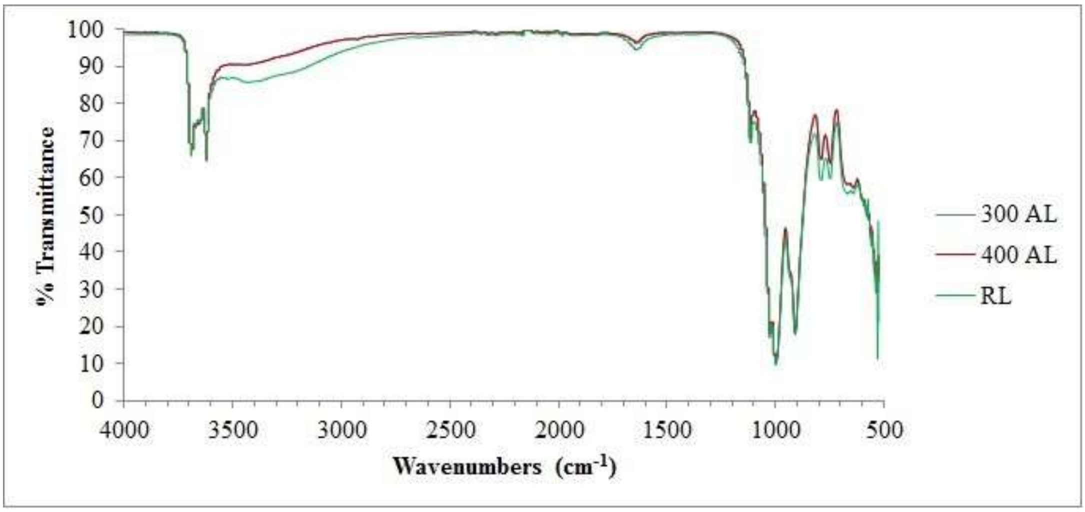

Figure 3: FTIR patterns of Raw, 300 ⁰C and 400 ⁰C Activated Laterite

3.2.5 The cation exchange capacity

The cation exchange capacity (CEC) for the soil samples was obtained as 9.22 cmol(+)/Kg for raw laterite, 9.74 cmol(+)/Kg for 300 ⁰C thermally activated laterite, and 9.64 cmol(+)/Kg for 400 ⁰C thermally activated laterite. Cationic impurities adsorb onto clay minerals mainly by cation exchange [36, 37].

3.2.6 The oil absorption and Swelling capacity

The oil adsorption capacity was tested for raw and thermally activated soil samples. Laterite soil showed a remarkably high oil absorption capacity (more than 96%) than the clay used in other studies, even without thermal activation (Table 3). The highest oil absorption capacity was obtained with 200 ⁰C thermally activated laterite soil (99.69%) and 100 ⁰C thermally activated laterite soil obtained 99.39% oil absorption capacity. Oil absorption was 97.21 percent in 300 ⁰C thermally activated laterite soil. Microbial testing revealed that, 100 ⁰C and 200 ⁰C thermally activated laterite soils contained microorganisms. The presence of microorganisms in cosmetics is not desirable. There for, 300 ⁰C thermally activated laterite soil is suitable to be used in applications that require high oil adsorption capacities, such as creams, powders, and emulsions.

According to US and British Pharmacopoeia of swelling capacity, the volume should be less than 22 mL in distilled water and more than 22 mL in sodium lauryl sulfate. Swelling capacity tests of the samples with distilled water showed the same performances (around 2 mL) and, in sodium lauryl sulfate-1%, around 24 mL (Table 3). These results indicate that, despite the good swelling capacity observed in all samples in an aqueous solution of sodium lauryl sulfate-1%, which can keep moisture away from the skin, promote skin health, prevent rashes, and provide comfort.

3.2.7 Artificial sweat absorption

When titrating the solution with a standard alkali such as KOH, initially, the organic acids present in the solution were neutralized (lactic acid and acetic acid), when formaldehyde is added to the solution, the ammonium salt ions existing in the solution combined with formaldehyde, liberating an equivalent amount of acid (HCl), which can be estimated by continuing the titration against the alkali.

$$4\ NH_4Cl + 6\ HCHO \longrightarrow 4\ HCl + 6\ H_2O + (CH_2)_6N_4$$

Here, the R_1 value corresponds to the amount of 0.1 M KOH consumed to neutralize lactic acid and acetic acid remaining in 5.0ml of the sample. The R_2 –R_1 value corresponds to the amount of 0.1M KOH consumed to neutralize HCl acid formed by the reaction of formaldehyde and NH^{4+} salt. When the concentration of NaOH in a solution is low, the concentration of lactic, acetic acid, and ammonium ions is likewise low. It indicates that, laterite soil has a high absorption capability (Figure 4).

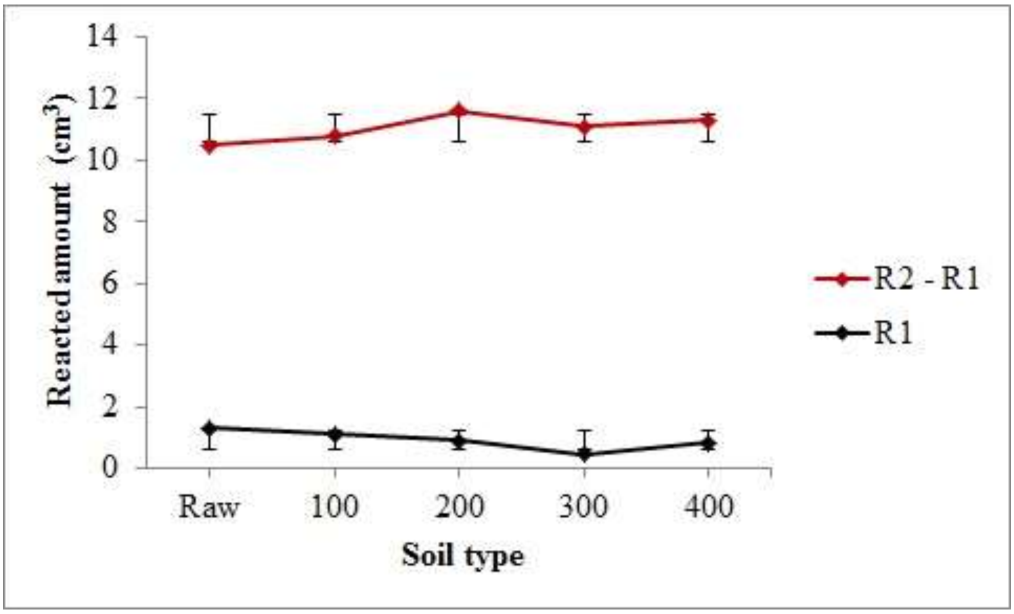

Figure 4: Artificial sweat absorption by laterite soil

Nevertheless, all soil types showed a high sweat absorption capacity when considering the raw and thermally activated laterite soil as adsorbents of organic acids such as Acetic acid and Lactic acid. Kaolin-rich soil is known for its high adsorbent capacity in removing organic dyes such as methylene blue from wastewater [38, 39]. This can be due to the physicochemical properties of laterite soil, such as pH, surface area, surface structure, and the functional groups on the surface.

3.2.8 FTIR data after absorbing sweat

FTIR spectra of each soil type before and after artificial sweat adsorption were obtained (Figure 5). In the OH stretching vibration region (3700–3300 cm^{-1}), the FTIR spectra show three absorption bands. At the region in 1634 cm^{-1} weak C=C stretching was observed. In the region of 1200–900 cm^{-1}, the four bands in the region were observed. Other than that, bands were observed at 788 and 529 cm^{-1}. However, the peaks had not changed significantly after artificial sweat adsorption in the soil types.

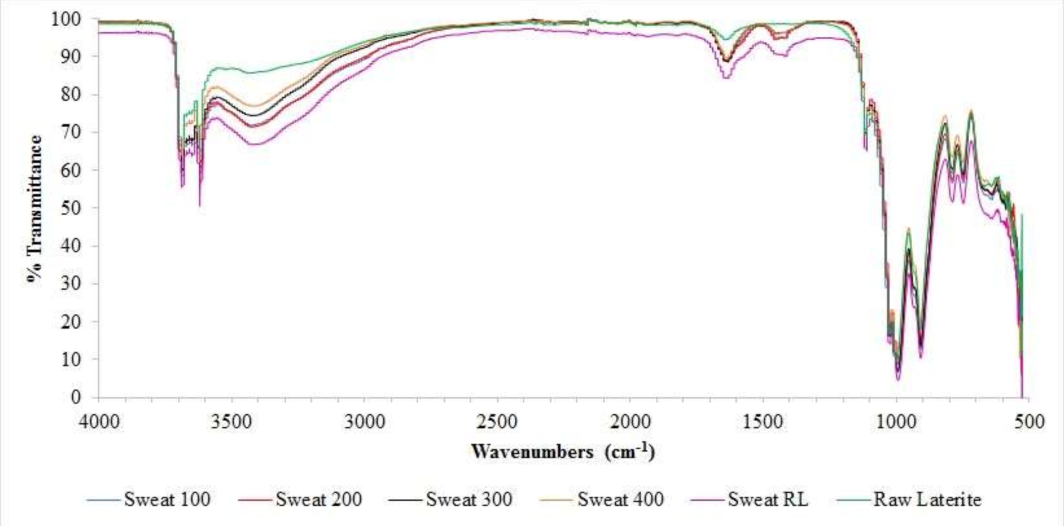

Figure 5: FTIR patterns of Laterite soils after sweat absorption

3.3 Microbiological analysis

The acceptable limits of total aerobic mesophiles must not exceed 5 × 10^{3} CFU/g or /mL [40]. There must be a complete absence of *Pseudomonas aeruginosa*, *Staphylococcus aureus,* and *Candida albicans* in 1 g or 1 mL [4, 5]. Raw laterite (up to dialution factor 10^{-5}), 100 ^{0}C (up to dialution factor 10^{-3}), and 200 ^{0}C (up to dialution factor 10^{-2}) samples showed uncountable growth of microorganisms. Few maggots and nematodes were detected after the 5th day of the raw laterite soil sample. The eggs, and cysts of maggots and nematodes abound in the soil [41] that they begin to grow in good environment. Therefor these soil samples are not good for cosmetic usage and 300 ^{0}C and 400 ^{0}C thermally activated laterite soil showed no growth of microorganisms even after seven days. These results showed that the 300 ^{0}C and 400 ^{0}C thermally activated soil samples are free from microorganisms and comply with the main requirements applied to clays for pharmaceutical and cosmetic purposes.

3.3.1 Microbial assay of the laterite soil

The results of the antibacterial assay determined by the agar well diffusion method for the product and the positive control

Amocxaline are represented in figure 6. As the negative control, deionized water was used. Compared with the antibiotic Amocxaline, a considerable antibacterial effect was seen regarding *Staphylococcus* and *Pseudomonas* species because of having the inhibition zone and it is measured as diameter of the zone. Thermal activation did not have an effect on the antimicrobial property of soil. Laterite soil types did not show a detectable anti-fungal effect.

Staphylococcus is a genus of gram-positive bacteria which is frequently found on the human skin surface in different species such as *Staphylococcus aureus, Staphylococcus epidermidis,* and *Staphylococcus warneri*. *Pseudomonas aeruginosa* is also a bacterial species that can be found on the human skin and can occasionally be pathogenic to humans. It is a gram-negative aerobic bacterial species that grow on the skin in moisture parts of the body. Therefore, we can conclude that this 300 ^{0}C and 400 ^{0}C thermally activated laterite soil is free from bacterial species, shows good antibacterial properties and fulfills the intended use of cosmetic products.

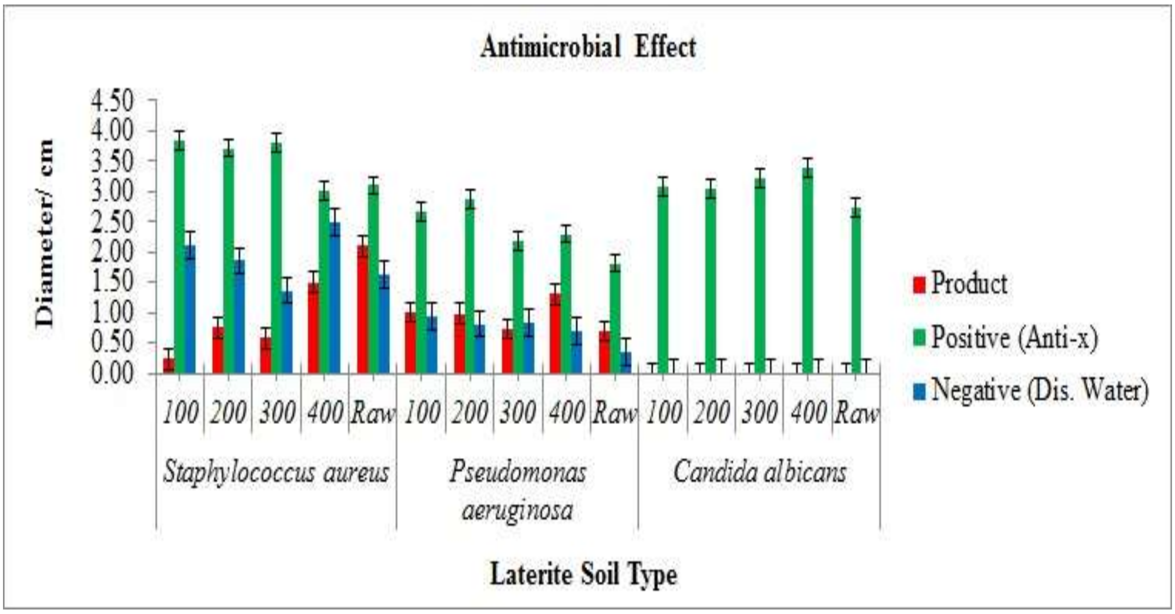

Figure 6: Antibacterial assays

4. CONCLUSIONS

The characterization of raw and thermally activated laterite soil samples' results of As test showed that samples present acceptable limits, and Pb and Hg are absent, established by the pharmacopeias for pharmaceutical and cosmetic products. The characterization results indicate that the raw and thermally activated laterite soil samples exhibit attractive characteristics, such as good oil absorption, good sweat absorption, and good swelling capacity in agreement with pharmacopeia. The thermally activated laterite soil samples are microbiological safety for making them suitable for cosmetic applications. Among the five analyzed laterite soil samples, 300 ^{0}C and 400 ^{0}C thermally activated laterite soil samples present the greatest potential for cosmetic applications.

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Competing Interests

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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