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Extraction and Characterization of Green Surfactants from Fruits of *Solanum Incanum* and *Solanum Aculeastrum*

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Abstract: Surfactants are surface active agents that lower the surface tension between two liquids or phases, and are used as emulsifying agents. Thus, they have two parts; polar and non-polar sections in the same molecule. These compounds can either be naturally occurring or synthetically manufactured. In Kenya there are plants which produces a lot of fruits, and juices from these fruits have been used traditionally as; soaps materials for washing clothes and other cleaning purposes, and as medicinal ointments. These fruits, though abundant have remained unutilized with the advent of modern washing and cleaning materials. The efficacies, quantities and qualities of these fruit juices has remained unknown to date. The general objective of this study was to extract green surfactants from fruits of *Solanum incanum* and *Solanum aculeastrum* and explore their properties and applications in the modern settings. The processing of these bio-surfactants involved, solvent extraction under controlled conditions of temperature, time, pH, solvent to feed ratio and properties of the feed material such as composition and particle size. Characterization was done for pH, surface active agents, metal cation and conductivity of the surfactants using pH meter FTIR, and conductivity meter respectively. Determination of the surfactant concentration levels using emulsification stability method. Agar disk-diffusion method was used to screen the in vitro antimicrobial activity of the extracted fruits surfactant. The percentage yield of the fruits surfactants was>50%, with *Solanum incanum* having highest of 65.063%. FTIR analysis showed the presence of saponin functional groups. UV-Vis analysis confirmed high concentration of saponins in the fruits of *Solanum aculeastrum* than *Solanum incanum.* The surfactants produced a stable foam reaching a maximum percentage height stability of 92.883% for the ripe fruits of *Solanum aculeastrum* and the scum formed was stable even after 3 days. The fruit surfactants inhibited the growth of both *E. coli* and *Candida albicans.* The results confirmed potentially high surfactant activity of the fruits extracts, indicating a promising future commercial applications and farming of these plants as cash crops.

Keywords; Biosurfactants, Surface active agents, surfactant activity cash crops, Saponins.

1 Introduction

1.1 Background of the study

Surfactants are compounds that lower the surface tension between two liquids and may act as detergents, wetting agents, emulsifiers, foaming agents and dispersants (Kimberly and Marion, 2010). They are usually organic compounds that are amphiphilic since they contain both hydrophobic groups and hydrophilic groups. They contain both water-insoluble component and a water-soluble component which diffuses in water and adsorbs at interfaces between air and water or at the interfaces between oil and water in the case where water is mixed with oil (Salager and Jean, 2002). From other studies, the fruits have been found to be rich in steroidal glycoalkaloids and sesquiterpenoids which exihibited antibacterial and antimycotic properties (Wanyonyi *et al.,* 2003).

Research has shown that, the fruits of *Solanum incanum* have been used for the treatment of cutaneous mycotic infections and other pathological conditions and that, the fruits extracts have high antifungal (Muhammed, *et al*., 2018). Also, other researches have reported that, crude fruits sap extract of *Solanum incanum* have phytochemicals associated with the insecticidal and detergent activity (Sambo, *et al.,* 2012).

The aim of the study was, to extract and characterize naturally occurring bio-surfactants from *Solanum aculeastrum* and *Solanum incanum* as potential candidates for use in cosmetics and ant microbial soap bases. Extraction of green surfactants with antibacterial properties for bathing and washing soaps gives the most effective surfactant as compared to the synthetic surfactants. This also provides less expensive surfactants due to the local naturally available raw materials.This was to provide an alternative and more effective antimicrobial additives for toilet soaps/bathing soaps/washing soaps which are less toxic and easily biodegradable. This also adds the economic values of these fruits which are inedible.

2 Materials and Methods

2.1 Experimental Design

A variety of laboratory methods were used to extract and characterize the fruits surfactants of *Solanum*

incanum and *Solanum aculeastrum*. The solvent extraction method was done using methanol in the ratio of fruits sap to solvent 1:5. The surfactant concentration levels of the fruit surfactant were done by determining the CMC, foam stability and its emulsification activity and this clearly indicated the surfactants efficiency. The antimicrobial activity of the fruits surfactant was also analyzed which involved the use of agar disk-diffusion method and tested against *E. coli* and *C. albicans.*

2.2 Description of the Sampling sites

Sampling was done in two areas. The first one was done in Maasai Mara University Botanical Garden in Narok County, Kenya which lies within 1.0863° S and 35.8767° E where samples of *Solanum incanum* fruits were obtained (figure 1). The second sampling was done in Keumbu, Kisii County, Kenya located within 0.7344° S and 34.8500° E (figure 2). Here, samples of *Solanum aculeastrum* were collected. The plants of *Solanum incanum* and *Solanum aculeastrum* are widely spread in these areas respectively.

Figure 1: Narok County, Kenya

Figure 2: Keumbu, Kisii County, Kenya

2.3 Sampling

Fruit samples were randomly collected by hand-picking from the selected plants. A minimum of 500g of each fruit samples was collected and carried to the laboratory using porous paper bags. In the laboratory, they were classified into two groups each; near ripe and ripe fruits.

2.4 Extraction of the fruits surfactant

2.4.1 Instrumentation and equipment

The following equipment and instruments were used: electronic balance, common laboratory glassware and apparatus,oven;Instruments used; pH meter, Cary 50UV-Vis Spectrophotometer, and FTIR.

2.4.2 Reagents and Chemicals

Fruit from the selected plants of *Solanum incanum* and *Solanum aculeastrum,* methanol, deionized water, potassium chloride, methylene blue dye, potassium nitrate, tri-sodium phosphate, and sodium hydrogen carbonate.

2.4.3 Procedure for the extraction of the fruits sap

Fruits from selected plants at two different stages of maturity were washed using distilled water and oven-dried at 60^0C overnight. The fruits were weighed using electronic weighing balance and crushed under mortar and pestle and the sap strained into a weighed 250mL beaker. The 250mL beaker with its contents was weighed. The samples were done in triplicate. The percentage of the fruits sap calculated using the following method and their averages calculated.

Fruits weight= W_f, Gross juice weight = W_j, Weight of the beaker = W_b, Net juice weight = $W_j - W_b$.

$$\text{Juice content \%} = \frac{\text{Net juice weight} \times 100}{\text{Fruit weight}}$$

2.4.4 Solvent extraction of the soap

A mass of 16.0g fruits sap from each sample was weighed into a 250mL conical flask and 80mL of 99.5% methanol added. The mixture was homogenized for 24hours through stirring using a magnetic stirrer and the aqueous medium obtained through filtration using Whatman filter paper no. 41s into a 250mL conical flask. The residue was discarded and the filtrate boiled in a water bath to evaporate the methanol leaving behind the fruit extract which was weighed and the percentage yield calculated. The pH of the extract now the fruit surfactant was measured using a pH meter and the values recorded. Both neat pH and the pH when 1mL of the sample was diluted to 100mL using distilled water were measured.

2.5 Characterization of the extracted fruits surfactant

2.5.1 pH Measurement

2.5.1.1 Neat pH Measurement

The fruit sap from each sample was transferred into a 100mL plastic beaker and the pH of the samples measured using a pH meter and their averages calculated.

2.5.1.2 pH of the fruit sap when diluted to 100mL

1mL of the fruit sap was put into a 100mL plastic beaker and the pH values of the samples measured using a pH meter and their averages calculated.

2.5.2 Test for Saponins

1mL of the fruit surfactant from each sample was put into a test tube and a drop of sodium bicarbonate

added and kept for 3 minutes. Any formation of froth which lasts for a long time was checked and the observations recorded.

2.5.3 Test for Carboxylic acid

A volume of 1mL fruit surfactant from each sample was measured using a 25mL measuring cylinder and put into a test tube. A drop of sodium hydrogen carbonate was added and the formation of a brisk effervescence was checked and the observations recorded.

2.5.4 Conductivity of the fruit Surfactant

The fruit surfactant from each sample was transferred into a plastic beaker and the conductivity measured using a conductivity meter. This was done in triplicate. The results were recorded and their averages and standard deviations calculated.

2.5.5 Carbon content Determination of the fruit

The fruits were cut into small pieces and air dried. 10.0g of the fruit samples were oven dried using small beakers for 3 hours and their masses weighed again. The difference between the two masses which gave the moisture content of the shade-dried fruits was calculated. The samples were then put into a weighed crucible with lid. The samples were ashed in the crucibles with lids. The ashes were left to cool and the mass of the ash + crucible + lid taken.

Mass of ash = (Mass of crucible+ lid + ash) – (Mass of crucible + lid)

The difference between the masses of oven dried sample and the ash sample gave the carbon content (combustible material). 1.0g of the ash was dissolved into 100mL of distilled water and stirred thoroughly and then filtered using Whatman filter paper no. 41. The mass of the residue and the oven-dried Whatman filter paper no. 41 was taken and the dissolved ash calculated. The pH of the ash solution and the percentage solubility was calculated using the following formula:

$$\text{Solubility \%} = \frac{\text{Mass of ash dissolved x100}}{\text{Mass of total ash 1g/100g of water}}$$

2.5.6 FT-IR Analysis

The fruit surfactant from different types of the fruits was put into a sample holder (polythene) whose background had been taken and the spectrum stored in the FT-IR machine as a standard so that its peaks don't collide with the peaks of the sample. The sample was run and the IR spectrum obtained for interpretation. The spectrum for the sample holder was also obtained and its peaks compared with the sample to check on the added peaks.

2.6 UV-Vis Analysis using UV-Vis Spectrophotometer

The samples of the fruit surfactants were subjected to UV-Vis spectroscopy for analysis of concentration of saponins in different types of fruits in both plants. The absorbance was measured at 240-360nm using a Cary 50UV-Vis Spectrophotometer. The concentrations of saponins was comparable after sketching a graph of absorbance against wavelength in nm.

2.7 Determination of the Surfactants Concentration Levels

2.7.1 Determination of Critical Micelle Concentration levels

A volume of 2mL fruit surfactant was put into a test tube and one drop of methylene blue dye added and the color of the solution noted. Two drops of 2M potassium hydroxide were to make the solution basic. This was followed with the addition of 3 drops of 2M potassium chloride which is an ionic strength adjuster. The change in color intensity was checked and the observations noted.

2.7.2 Foam generation

A volume of 3mL fruit surfactants was measured into test tubes and 2mL of distilled water added. The solutions were shaken and the height of the foam measured and recorded. The foam stability was determined by measuring the heights of the foam after 10 mins and the percentage by height stabilities calculated. This was repeated three times and with comparison with laboratory soap.

2.7.3 Emulsification activity

The emulsification activity of the fruits surfactant was determined by adding 1mL of 2M calcium chloride and magnesium chloride to 2mL of the surfactant respectively. The formation of scum on the surface of the surfactant was noted. The initial formation of the scum was compared with the final scum after 3 days.

2.8 Antimicrobial Testing

2.8.1 Procedure for antimicrobial testing

Distilled water was measured as per the quantity of the media to be prepared and poured into the glass bottle. The calculations for the culture medium to be prepared was made, weighed using the weighing balance and then poured into the distilled water in the glass bottle and sterilized by autoclaving at 121^0C for 15minutes.

The media was allowed to cool and dispensed into the Petri dishes and let to set and then inverted. The bacterial and the fungi cultures to be tested were impregnated onto the surface of the media. The filter paper discs were soaked with the fruit surfactant samples and the soaked disc placed on the media (impregnated fungi or bacteria) and incubated using an incubator for 24 hours at 37^0C. Any zone of inhibition (clear zone) was checked and the diameters measured and recorded in mm. This was done in triplicates.

3 Results and Discussion

3.1 Overview

The collected data was represented in the form of tables, pictures, and graphs in this chapter. The analysis was done by comparing different results of the different types of fruits from the two selected plants to determine the efficiency of the fruits surfactants/bio-surfactants obtained from these fruits.

3.2 Fruit sap extract

3.2.1 Yield of the fruit sap

Figure 3 below shows the graph of the percentage yield of the fruits sap produced by the different types of fruits from the two plants.

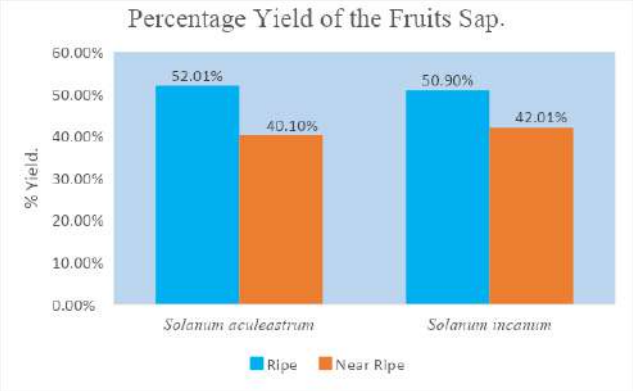

Figure 3;Percentage Yield of the Fruits Sap

The results from figure 3 above indicated that, the mean percentage yields of greater than 50% was obtained for the ripe fruits than the near ripe fruits. Furthermore, the yield of the fruits sap from the two plants was almost the same with *Solanum aculeastrum* showing a slightly higher mean yield of 52.007±4.913% for the ripe fruits and *Solanum incanum* 42.007±2.143% for the near ripe fruits (Adebanjo, *et al*., 2016).

3.2.2 pH Measurement

The neat pH and the diluted pH were statistically analyzed and recorded. The results showed that the near ripe fruits were more acidic than the ripe fruits for the two plants. However, the pH for *Solanum incanum* fruits was weakly acidic (>5.0) than *Solanum aculeastrum* which was slightly <5.0 as shown in the figures 4 and 5 below.

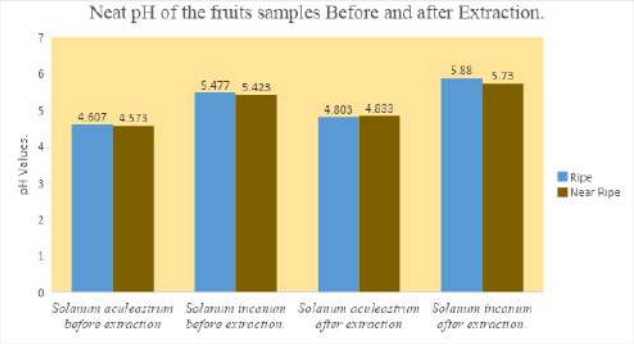

Figure 4;The neat pH Values of the fruits samples before and after Extraction

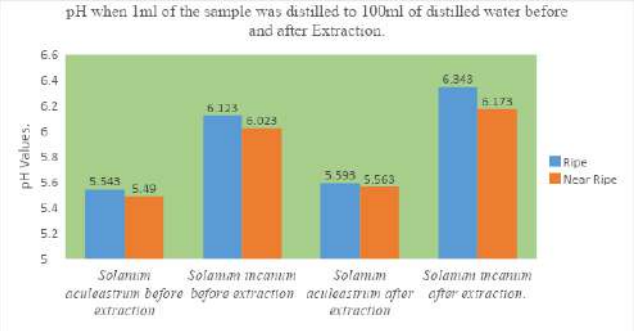

Figure 5; The pH values of 1mL of extract diluted to 100mL with distilled water.

These values increase significantly during the extraction process leading to less acidic extracts as compared to the initial pH values of the fruits sap. When 1mL of the sample was diluted to 100mL, the pH increased clearly showing their differences with the maximum mean values reaching 5.593±0.0252 and 6.343±0.0666 of ripe fruits of *Solanum aculeastrum* and *Solanum incanum* respectively. The acidity of these fruits sap could be attributed to the presence of carboxylic acid which was confirmed present. The increase in the pH values after extraction was because the weakly basic solvent used might have reacted with some of the weakly acidic fruits sap. However, these pH values are in line with the pH values of human body skin which ranges between 4.2 and 5.6 (Saba and Yosipovitch, 2013, Schmid and Korting, 2006).

3.3 Yield of the Fruits Surfactant

The amounts of the fruits surfactant obtained at different stages of the fruits development of *Solanum aculeastrum* and *Solanum incanum* and their percentage yields were obtained as shown in Figure 6. Which shows a graphical comparison of the percentage yield of the two different types of fruits from *Solanum incanum* and *Solanum aculeastrum.*

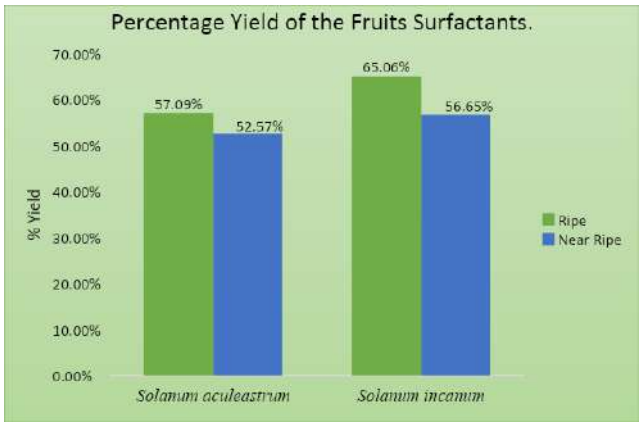

Figure 6;Percentage Yield of the Fruits Surfactants

The yield of the fruits surfactant was higher for *Solanum incanum* than in *Solanum aculeastrum* indicating a maximum average yield of 65.063±2.3626% and 57.087±1.4533% for the ripe fruits respectively. The near ripe fruits presented slightly lower percentage yields than ripe fruits with *Solanum incanum* showing a higher mean percentage yield of 56.647±1.6453 (Sabrina, *et al*., 2018).

3.4 Conductivity of the Fruits Surfactant

Figure 7below shows the conductivity of the fruits surfactants of the two types of fruits. The graphical trending of the conductivity values are shown for easy comparisons.

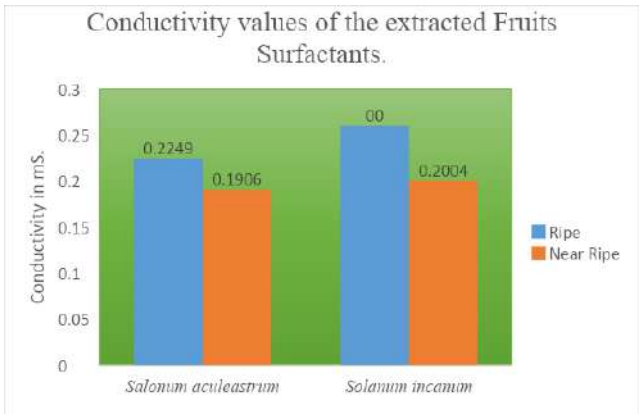

Figure 7; Conductivity values of the extracted Fruits Surfactants

The conductivity values indicated that ripe fruits of *Solanum aculeastrum* had higher conductivity values than the near ripe fruits reaching an average of 0.22490±00183mS. In comparison with *Solanum incanum*, the conductivity increases to a maximum mean value of 0.26000±00159mS for the ripe fruits. The results showed that ripe fruits surfactant of both plants has greater conductivities than the near ripe fruits. Nehaand coworkers (2018) in their research on a new novel an ionic surfactant reported that, electrical conductivity of an ionic surfactant increases with increasing surfactant concentration. This could then mean that, the increased conductivity above could be attributed with the presence of an ionic surfactant whose counter ion could be potassium ions, which were confirmed present in the fruits surfactants, (**Figure 7**).

3.5 Test for Saponins

An aqueous solution which was suspected to contain saponin after addition of a drop of sodium bicarbonate, a froth which lasted for a long time was formed and this confirmed the presence of saponin in the solution. The yellow color of the solution in the test tubealso showed the presence of saponin (Harvey, 2012). Saponins have surfactant properties (Yamanaka *et al*., 2008) and hence their presence in the fruits sap indicates their detergent properties.

3.6 Test for carboxylic acid

On addition of sodium hydrogen carbonate pellets to the fruits surfactant, there was the production of effervescence/bubbling which confirms the presence of carboxylic acid. The pH values also confirmed the acidity properties of the fruit surfactant.

3.7 Moisture content, Carbon content and Solubility determination

3.7.1 Moisture content

The moisture contents were analyzed and recorded as shown below.The percentage moisture of *Solanum incanum* was higher than *Solanum aculeastrum* as shown in figure 8 below.

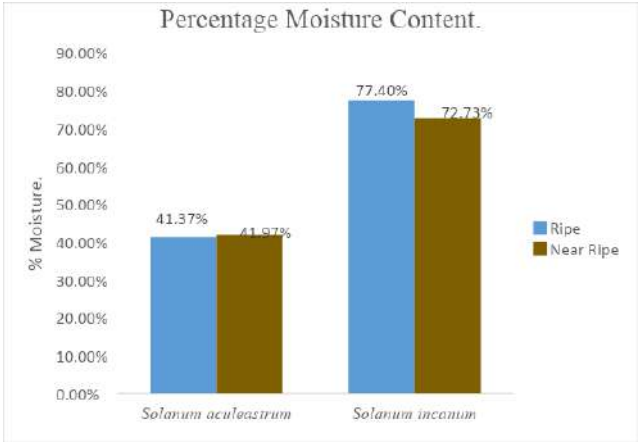

Figure 8;Percentage Moisture Content

The results show that *Solanum incanum* has more moisture content with ripe fruits indicating a high percentage of 77.40±0.6% than *Solanum aculeastrum* with the near ripe fruits showing a slightly higher percentage of 41.967±1.8583%. *Solanum aculeastrum* shows slightly low percentage in ripe fruits of average 41.367±4.2360% than near ripe fruits. This findings were different from that of Adebanjo, et al., (2016), who reported a moisture content slightly lower in ripe tomato fruits that that of the unripe ones.

3.7.2 Carbon content

Carbon contents of the different types of fruits from the two plants were determined and recorded as shown.The percentage carbon contents were represented in the bar graph as shown in figure 9below.

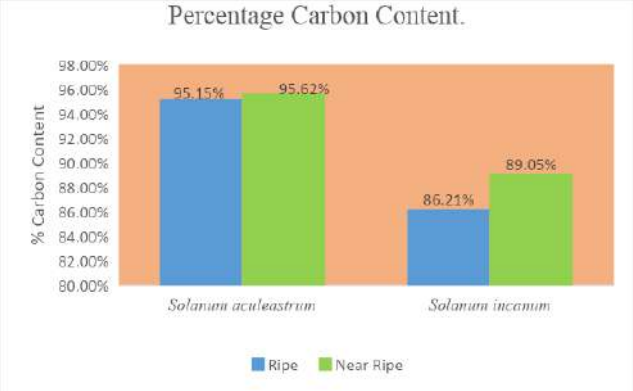

Figure 9; Percentage Carbon Content

This shows that *Solanum aculeastrum* has more carbon content reaching a maximum percentage averages >90% as compared to *Solanum incanum* which was <90%. The near ripe fruits showed a high percentage of carbon content than ripe fruits for both plants. Particularly, *Solanum aculeastrum* had the highest mean value of 95.623±0.5713%. Moirangthem and Tucker (2018) in their study showed that, fruits emit lots of ethylene gas during ripening. They also reported that different fruits releases different a mounts of these ripening gas. Hence, the different amounts of carbon contents in the ripe fruits, near ripe fruits and the fruits of the two types of species as shown from **Figure 9** above.

3.7.3pH Measurements of the Ash samples

These values showed that the ash solutions were basic and significantly comparable as shown in the figure 10 below.

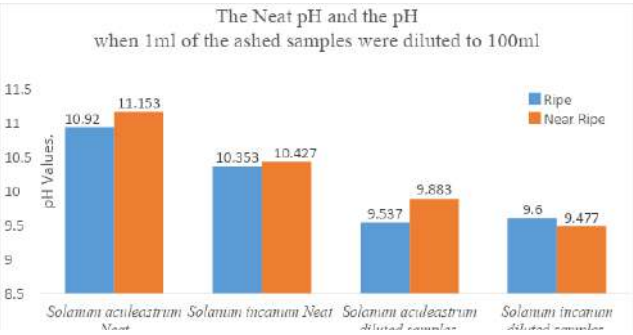

Figure 10; The neat and the pH values when 1mL of the ash samples were diluted to 100mL

These values correspond to the pH values of ash which range from 10-12. The pH when 1mL of the ash solution was diluted to 100mL of distilled water was slightly lower reaching a minimum value of 9.477±0.1168 in near ripe fruits of *Solanum incanum* than neat pH. However, the results show that *Solanum aculeastrum* was more basic with the maximum value reaching a mean value of 11.153±0.0551 than *Solanum incanum.* Adebanjo, et al., (2016) in their research had reported higher ash content in ripe tomatoes than in the unripe ones. Equally other studies have shown different mineral contents of ripe and unripe fruits, possibly a reason for different solubility and pH values(Sabrina, *et al*., 2018).

3.8 FT-IR Analysis

3.8.1 FT-IR Analysis of the extracted fruits surfactants

The FT-IR analysis for the fruits surfactants from the different types of fruits of both plants was run and the spectrum obtained as shown in the figures 13, and 14, below for analysis. A standard for saponins was also obtained for comparison.

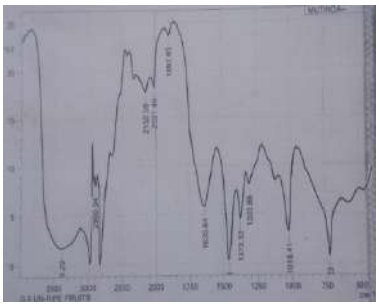

Fig. 11; Near-ripeof *Solanum aculeastrum*

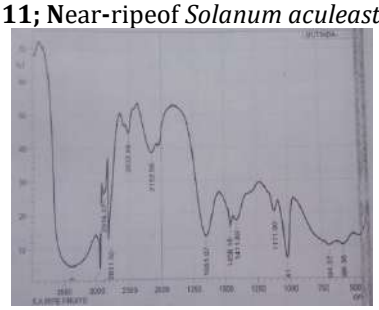

Fig.12; Ripe of *Solanum aculeastrum*

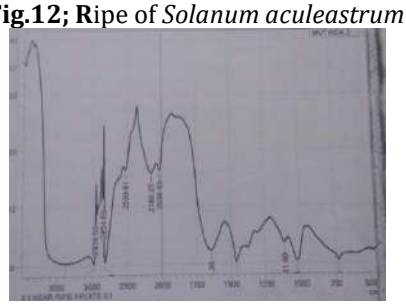

Fig. 13;FT-IR for near ripe fruits of *Solanum incanum*

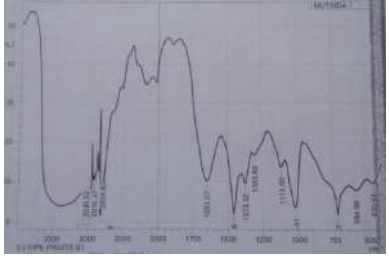

Fig. 14;FT-IRspectrum for ripe fruits of *Solanum incanum*

Saponin was confirmed present in the extracted fruits surfactant by infrared absorption spectrum and compared with that of the standard. All the spectra of both ripe and near-ripe fruits showed a characteristic broad infrared absorbance of the hydroxyl group (OH) ranging from 3500cm^{-1} to 3290 cm^{-1} (Neha, *et al*., 2018, Rohman, *et al*., 2011). The standard saponin also showed this characteristic OH stretch. This very broad peak confirms the OH for carboxylic acids which were earlier confirmed present.

There was a carbon-hydrogen (C-H) infrared absorption ranging from 2800 cm^{-1} to 2900 cm^{-1} in all the samples of the fruits surfactants. This was evident also in the standard saponin. There was C=O at 1636 cm^{-1} for near ripe fruits of *Solanum aculeastrum,* 1651 cm^{-1} for the ripe fruits, 1651 cm^{-1} for ripe fruits of *Solanum incanum* and 1643 cm^{-1}for the near ripe fruits infraredabsorption. This range is for carboxylic acids which range from 1630-1700 cm^{-1} (Meshari and Mohammed, 2014, Neha, *et al*., 2018). This infrared absorption was also evident in the standard for saponin at 1643 cm^{-1}.

The fruits surfactants extracts of near ripe and ripe fruits of *Solanum aculeastrum* and the ripe fruits of *Solanum incanum* showed an IR absorption at 1018 cm^{-1} while that of *Solanum incanum* near ripe showed at 1026 cm^{-1}. This was the oligosaccharide linkage to sapogenin (C-O-C) which was also seen at 1026cm^{-1} of the standard (Meshari and Mohammed, 2014). In all fruits surfactant samples, there was a C=C stretch at 1458cm^{-1} and 1450cm^{-1} in the standard which signifies an aromatic peak. These results indicated that this was an acidic saponin present in these samples. The presence of saponins which have detergent properties confirms their surfactant activity and the antimicrobial activity of the extracted bio-surfactants.

3.9 UV-Vis Analysis

A curve of absorbance against wavelength in nm of the fruits surfactants was obtained for comparison of the concentration of saponins in the two plants as shown in figure 15 below.

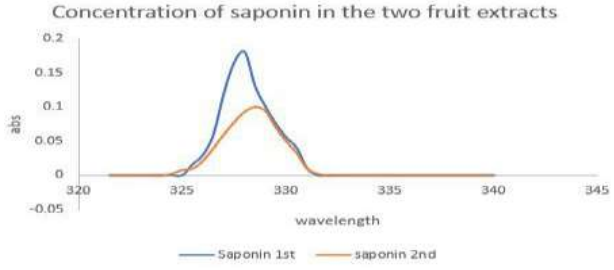

Figure 15; Concentration of Saponin in the 1st*S. aculeastrum* & 2nd*S.incanum*).

The results indicated that *Solanum aculeastrum* had higher concentration of saponins than *Solanum incanum*. This is evident by a very strong light absorption near 328nm which is the region for saponin absorption which usually ranges from 240-400nm (Benyong*et al*., 2014). The high concentration of saponin in *Solanum aculeastrum* contributed to their effectiveness in antimicrobial activity than *Solanum incanum* which was associated to presence of saponins in the fruit surfactants.

3.10 Surfactant Concentration Levels

3.10.1 Determination of Critical Micelle Concentration Levels (CMC)

On addition of one drop of methylene blue dye to the fruit surfactant, the whole solution turned blue in color. Adding 2M potassium chloride to the solution, the intensity of the solution color changed with light green coloring on the foam level. The color changes due to the formation of insoluble micelles above the CMC level which absorbs the water-insoluble dye. Lack of change of the color of the dye on addition the surfactant was because the surfactant was below the CMC level indicating its efficiency (Geisher and Richardson, 2005). Addition of potassium chloride which is an ionic strength adjuster induces the formation of micelles which absorbs the dye making its color to change.

3.10.2 Foam generation

The Figure 16 shows the initial foam generation heights and the heights after 10 minutes to determine the foam stability and the percentages.The tabulated results were represented in form of bar graph as shown in the figure 16 for easy interpretation.

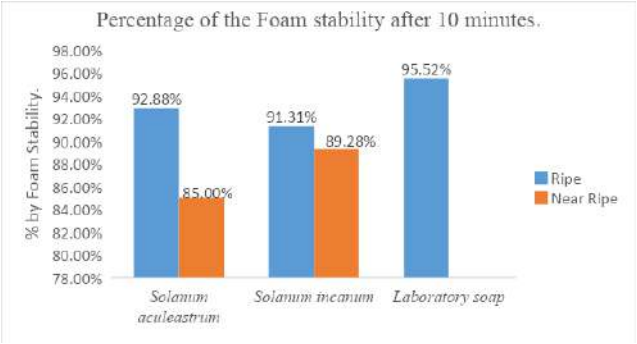

Figure 16; Percentage of the Foam stability after 10 minutes

The results show that all the surfactants from different types of fruits had a percentage mean values ≥85% with ripe fruits of both plants having higher mean percentages of 92.883±2.9599% and 91.313±3.1927% than near ripe fruits. This indicates that the surfactants form a very stable foam and hence their effectiveness. Neha, *et al*., (2018) in their study of an ionic surfactant showed that, foam stability was directly proportional to the surfactant concentration in solution. In comparison with the laboratory soap, the difference was small. The foam formation could be associated with the presence of saponins confirmed.

3.10.3 Emulsification activity

On addition of 2M calcium chloride and magnesium chloride to the fruit surfactant separately, there was the formation of scum on the surface. After 3 days, the scum remained stable. The scum stability indicated the surfactants efficiency and can last for a long time with its surfactant property (Fablola *et al*., 2017).

3.11 Antimicrobial Testing

3.11.1 Antibacterial testing

The fruit surfactant was tested against *E. coli* and the results analyzed and tabulated as shown below. Figure 17 below shows that the fruits surfactant from all different types of fruits of the two plants inhibited the growth of *E. coli.*

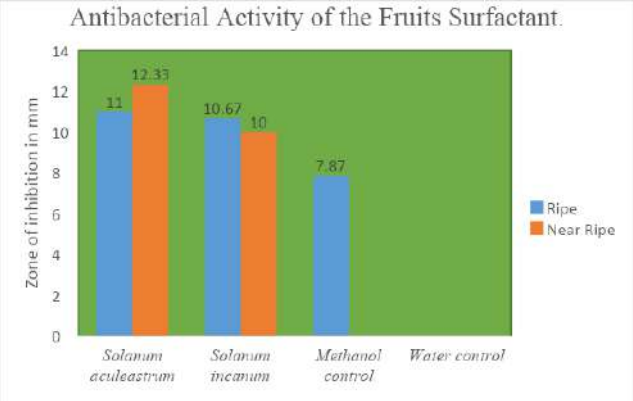

Figure 17; The Antibacterial activity of the Fruits Surfactant

The diameter inhibited reached a maximum mean zone of inhibition of 12.33±0.577mm in near ripe fruits of *Solanum aculeastrum. Solanum aculeastrum* showed higher antibacterial property in both fruit types than *Solanum incanum.* The antibacterial property of the fruits surfactant could be linked to the presence of saponins (Abbasoku and Turkoz, 2008) which was confirmed present in the fruits surfactant. Methanol which was used as a control experiment also showed the antibacterial activity reaching an average value of 7.87±0.6658mm which was considerably lower than all the test samples of the fruit surfactants.

3.11.2 Antifungal testing

Figure 18 below shows the tabulated results of the antifungal activity of the fruits surfactants. The results show that *Solanum aculeastrum* recorded the highest measured average zone of inhibition that successfully inhibited the growth of *C. albicans.*

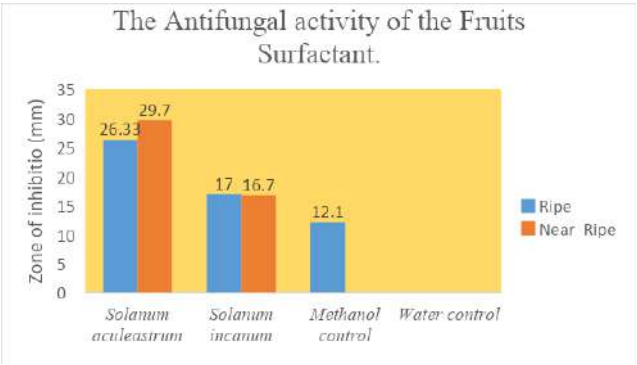

Figure 18; The Antifungal activity of the Fruits Surfactant

This was susceptible as compared to *Solanum incanum* which was considerably small with the ripe fruits recording the highest of 17±6.0828mm. The zone of inhibition reached a maximum mean value of 29.667±5.0332mm in near ripe fruits of *Solanum aculeastrum*. The antifungal property of the fruits surfactant might be due to the presence of saponins (Abbasoku and Turkoz, 2008) which was confirmed present.

4.0 Conclusion

The percentage yield of both fruits sap and the fruits surfactant was higher for the ripe fruits from both plants. This percentage reached an average value of 52.007±4.9134% and 65.063±2.3626% for *Solanum aculeastrum* and *Solanum incanum* respectively. Both fruits sap and the extracted fruit surfactant was weakly acidic with pH values ranging from 4.5-5.90 due to the presence of carboxylic acid.The results showed that fruit composition was influenced by the ripening stage of the pulps and the ripe samples presented higher content of carotenoids and lipids. The conductivity was higher for the ripe fruits and the FTIR analysis confirmed the presence of saponins. UV-Vis analysis showed high concentration n of saponins in *Solanum aculeastrum* than *Solanum incanum.* The fruits had high carbon contents reaching an average of ≥85% for *Solanum aculeastrum*. The foam stability of the surfactants was quite high. The stability of the scum after 3 days indicated the surfactants long life durability. The surfactant was confirmed to have antifungal and antibacterial property and worked against the *E. coli* and *Candida albicans*. This activity was due to the presence of saponins.

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REFERENCES

[1] Abbasoku U. and Turkoz S. (2008). Antimicrobial Activities of Saponin Extract from some Indigenous Plants of Turkey. *International Journal of Pharmacognosy volume 33*,293-296.

[2] Benyong H., Chen Y., Ren Y. and Cheoyin C. (2014). Content determination of total Saponins from Opuntia. An Indian Journal of Biotechnology, volume 10, issue 18, 10400-10404.

[3] Fablola C. G., Nathalia M. P., Hugo M. M., Alicia M. T., Juliana M. L. and Leonie A. S. (2017). Physio-chemical Properties of the Bio-surfactant Obtained from Fruit Extract of *Genipa americana* L. and *Tamarindus indica* L. and its Application in Oil Removal. *Journal of Chemical Engineering Transactions*, volume 57,978-88-95608-48-8, 1549-1554.

[4] Geisher R. and Richardson J. (2005). Methods for Determining Surfactant Concentration in Aqueous Solutions. *Journal of Chem Treat*, 10-25.

[5] Harvey, D. J. (March 01, 2012). Analysis of carbohydrates and glycoconjugates by matrix-assisted laser desorption/ionization mass spectrometry: An update for 2007-2008. *Mass Spectrometry Reviews, 31,* 2, 183-311.

[6] Kimberly Q. and Marion S. (2010). Surfactant, Soap, and Detergents. *Journal of Toxicology*, 1-3.

[7] Meshari S. A. and Mohammed A. (2014). Direct Detection of Saponins in Crude extracts of Soapnuts by FTIR. Journal of Natural Product Research; 29(13), 1-5.

[8] Moirangthem K and Tucker G (2018) How Do Fruits Ripen?. Front. Young Minds. 6:16. doi: 10.3389/frym.2018.00016

[9] Muhammed V., Beaman M. and S. I. (2018). Antibiotic Action of *Solanum incanum. Journal of Antimicrobial Agents and Chemotherapy*, 920-924.

[10] Rohman A., Che Man Y. B., Ismail A. and Puziah H (2011). FTIR Spectroscopy Combined with Multivariate Calibration for Analysis of cod liver oil in Binary mixture with Corn oil. Journal of International food Research; 18: 757-761.

[11] Saba M. A. and Gil Y. (2013). Skin pH: From Basic Science to Basic Skin Care. *Journal of Acta Derm Venereol* 93, 261-267.

[12] Salager and Jean L. (2002). Surfactants, Types and Uses. Published by Laboratorio, FIRP, Escuela de ingenieria Quimica, Universiadad de los Andes, Merida 5101 Venezuela.

[13] Sambo H. S., C. S. Pam and Dahiru D. (2012). Effect of Aqueous Extract of *Solanum incanum* Fruit on some Serum Biochemical Parameters. *Journal of Agriculture, Business and Technology*, 82-86.

[14] Schmid-Wendtner M. H. and Korting H. C. (2006). The pH of the Skin Surface and Its Import on the Barrier Function. *Journal of Skin Pharmacology and Physiology*; 19, 296-302.

[15] Wanyonyi A. W., Tarus P. K. and Chhabra S. C. (2003). A novel Glycosidic Steroidal Alkaloid from *Solanum aculeastrum. Journal of Bull Chemistry SOC Ethiop*, 61-66.

[16] Yamanaka, T., Vincken, J.P., Waard, P., de, Sanders, M.G., Takada, N., & Gruppen, H. (2008). Isolation, Characterization, and Surfactant Properties of the Major Triterpenoid Glycosides from Unripe Tomato Fruits. *Journal of Agricultural and Food Chemistry* 56 (2008) 23.

[17] Neha, S., Nilanjan, P., Keka, O., Swapan, D. and Ajay, M., (2018). Synthesis, characterization, physical and thermodynamic properties of a novel anionic surfactant derived from Sapindus laurifolius. *DOI: 10.1039/C8RA03888K (Paper) RSC Adv., 2018, **8**, 24485-24499.*

[18] Adebanjo, A. B., Adeyemi, P. A., and Victor, N. E., (2016). Changes in Nutrient Composition, Antioxidant Properties, and Enzymes Activities of Snake Tomato (*Trichosanthes cucumerina*) during Ripening. *Prev Nutr Food Sci. 2016 Jun; 21(2): 90–96. doi: 10.3746/pnf.2016.21.2.90.*

[19] Sabrina, S. M., Stephanie, R., Marcela, B. S., Jacob, P., Roger, W., Claudia, S. da R., (2018). Evaluation of the chemical, sensory and volatile composition of sapota-do-Solimões pulp at different ripening stages. *https://doi.org/10.1016/j.foodres.2018.04.033.*