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Comparative Analysis of Soap made from different composition of Mango Kernel Oil and Coconut Oil with two other Commercial Soaps

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Abstract The mango kernel oil (MKO)was extracted mechanically. The MKO was characterised and used in the preparation of soap along coconut oil (CNO). The analysis of MKO (using AAS) for elemental composition revealed that it has predominantly; Na (162.59 mg), Mg (10.077 mg), and Mn (6.866 mg). Meanwhile, the FTIR analysis gave characteristics peak of 2922.2-2855.1 cm^{-1} and 1744.4 cm^{-1}implying the presence of C-H stretch from saturated and unsaturated compounds and then ester/aldehyde/ketones/carboxylic acid, respectively. The masses of the four soaps prepared using MKO and CNO in the ratio 100:0, 0:100, 50:50, 20:80, respectively was found to be 11.14 g, 10.59 g, 10.93 g and 10.20 g. Soaps from 100% MKO, 50% MKO: 50% CNO, and the two commercial soaps have excellent total fatty matter TFM (of 76% and above), unlike soaps from 100% CNO and 80% CNO (less than 76%). The soaps also indicated acceptable total alkali levels of 0.16 – 0.36%. All the prepared soaps have lower pH values (less than 9) unlike the commercial soaps whose pH values were above 9. While the prepared soaps exhibited foam height of 4.00 mL, 3.90 mL, 3.80 mL, 3.70 mL for the soap samples A, B, C, and D; the commercial soaps had foam heights of 5.0 mL and 5.50 mL, respectively for E and F. It was found that the commercial toilet soaps and the 100% MKO soaps were highly effective in cleaning than the soap prepared with 100% CNO. This again shows that MKO should be a choice oil among others in soap making.

Keywords Oil, Soap, Waste valorization, Waste minimization, Green Chemistry

1. Introduction

We all depend largely on bathing and laundry activities for our healthy living; in which soap is an integral part. Although the preparation of soap is same worldwide, it is produced in different varieties for various purposes. Soap as we know is a Na/ K salt of various naturally occurring fatty acids obtained via saponification process. It can be made into in bars, granules, flakes, or liquid form [1]. The commonest oils used in making soap are lard, tallow, coconut, palm, and olive oils[2]. Often times, 1 –7% excess fat is used to reduce the harshness of soap, provide dense creamy lather, and to ensure smooth and soft skin[3]. More so, most abundant saturated fatty acids are palmitic and stearic acids, whereas common unsaturated fatty acids are oleic and linoleic acids. Production of quality soap is a function of choosing the right proportions of the right oils with their different fatty acids. Therefore, for the quest of efficient bioderived resource management and search for less commonly used oils in soap making with peculiar benefits, MKO has been considered, with significant underutilization. It is felt that increase in the use of MKO for soap production will bring a lot economic and environmental advantages. This paper is seeking to advocate massively the utilization of MKO in soap making.

Now, mango (*Mangifera indica L*) is one of the most economically important fruit. Mango seed consists of tenacious coat enclosing the kernel. The seed content of different varieties of mangoes ranges from 9% to 23% of the fruit weight and the kernel content of the seed ranges from 45.7% to 72.8% [4]. It is now cultivated and grown extensively in many tropical regions and is widely distributed worldwide [5-7]. Many aroma-causing functional groups have been identified in mangoes, including alcohols, terpenes, carbonyls, and esters. Recently, the fatty acid composition of 4 varieties of mango seed oil from Kenya was determined, and the oil was found to comprise oleic acid, stearic acid, linoleic acid, and palmitic acid. Mangocontains antioxidants such as carotenoids, polyphenols, and tannins which are known for their beneficial effect on free radical elimination, life style disease control and blood cholesterol prevention [5]. Fatty acids are important as nutritional substances and metabolites in living organisms. Many kinds of fatty acids play an important role in the regulation of a variety of physiological and biological functions. The main fatty acids found in mango kernel oil are about 45% oleic acid and 38% stearic acid. Oleic acid is an 18 – carbon monounsaturated fatty acid, useful in human nutrition and helps reducing triglycerides, cholesterol, and glycemic index. Stearic acid on the other hand is also a long C_{18} straight chain, but a saturated fatty acid which has been found to bind and plasticized composites, human serum albumin, and helical sites in bio-molecules [4].

A wide variety of processed products derived from mango include canned whole or sliced mango pulp in brine or in syrup, mango juice, nectar, jam, sauce, chutney, and pickle etc [8]. It is one of the most extensively exploited fruits for food, juice, flavor, fragrance and colour, and a common ingredient in a new functional foods often called super-fruits [9]. Mango kernel oil has been used in the cosmetics industry as an ingredient in soaps, shampoos, and lotions because it is a good source of phenolic compounds including micro-elements like selenium and zinc [4]. Unfortunately, most factories that make use of mango fruit as their raw material for the production of fruit juice used to discard the mango seed kernel as a waste product. This waste product after pilling them up for several times generates offensive odour, thereby polluting our smooth environment and making life difficult for the inhabitants of such environment. This research work is centered on how this waste can be processed into MKO for soap making, hence littering of our environment with mango seed kernel will be prevented. Therefore, the research work will benefit us in waste minimization (in conformity to the Green Chemistry Principles) and enhance MKO use. In recent times we can see a lot attention about waste valorization and prevention becoming topical among researchers and policy makers. Therefore, many researches have been reported especially on biomass waste valorization [10-14]. Hence, we report comparative analysis of soap made from different composition of mango kernel oil and coconut oil with two other commercial soaps.

Materials and Methods

Materials/ Apparatus and Equipment

Mango, NaOH, Phenolphthalein, HCl, H_2SO_4, HNO_3, Deionised water, H_2O_2, Lux, Dettol, 250 mL Beakers, 250 mLconical flask, 25 mL pipette, Burette, Retort stand and clamp, White tiles, Volumetric flask, Spatula, Funnel, Analytical weighting balance (PW 184), Atomic Absorption Spectrometer (PG990), UV-spectrometer (Shimadzu UV-1700), FTIR spectrometer (Shimadzu IR affinity-1 and Nicolet 6700), Watch glass, Glass beads, Fume cupboard, Thermometer, Stop watch, pH meter(HI 9024), Measuring cylinder, Filter paper, test tube, thermometer were used for the research.

Sample collection, Pretreatment and extraction

Mango fruit samples were obtained from Logo I, in Makurdi Local Government Area of Benue state – Nigeria. Mango seed were recovered from these fruits. Then, the seeds were well sun-dried for about two weeks and cracked to obtain the kernels. Eventually, the mango kernel oil (MKO) was extracted mechanically.

Methods

Digestion of MKO for metal analysis

The MKO digestion prior to the elemental analysis using AAS was carried as previously reported by Asemave *et al*. [15]

Spectroscopic Analyses of the MKO

The FTIR and UV-visible analyses was performed also using about 50 mg of the MKO in each case. The UV-visible was performed in n-hexane.

Preparation of Soaps from MKO

3.02g pellets of NaOH were measured and were dissolved in 5.84mL of distilled water in cold water bath. The solution of NaOH was allowed to cool down to 27℃. While NaOH solution was been cooled, about 5g of MKO was placed in water bath for heating so as to melt the oil. The oil was stirred as it melts. As the temperature of MKO approaches 27℃, the solution of NaOH prepared was slowly added to the oil in a beaker with gentle stirring until when the mixture turned to slurry. The resultant mixture (soap) was poured into mould and allowed to cool for 24 h. The soap prepared was allowed to cure for 4 weeks so as to make the soap harder, last longer and have a better lather. The procedure above was followed to prepare all the soaps; A (100% MKO); B (100% CNO); C (50% MKO: 50% CNO); D (20% MKO: 80% CNO), respectively [16].

Determination of the pH of Soaps

About 1 g soap and 99 mL distilled water were weighed out. Then the distilled water was heated up to 70°C and the soap was added to the distilled water and stirred well until soap dissolved. Then solution was cooled in ice bath (40 °C) and pH was measured by using pH meter as previously performed [16-17].

Foaming Ability Test of Soap

2.0g each of the soap shavings was put into a 500mL measuring cylinder with 100mL of distilled water. The mixture was vigorously shaken in order to produce foam. After shaken for 2min, the cylinder was allowed to stand for 10min and the height of the foam in the measuring cylinder was measured and recorded [18].

Test for Effective Cleaning of the soaps

This is determined by dropping oil on six separate filter paper and the oil was allowed to diffuse into the filter papers for 1min. The filter papers with the oil spot were immersed in separate beakers containing each of the soap solution (2.0g soap shavings/ 100mL distilled water). Each was agitated for 1min. The filter papers were removed and rinsed with distilled water and the effectiveness of cleaning in each filter paper was visually observed [18].

Determination of Total Fatty Matter (TFM) of the Soaps

About 4g of the soap sample was dissolved in 60 mL of distilled water and heated then followed by addition of 8mL of 15% H_2SO_4while heating until a clear solution is obtained. The fatty acid present in the solution was solidified on addition of 2.8 g of bee wax and reheated. The solution was allowed to cool to form a cake; the cake was removed and washed. Total fatty matter was calculated by using: %TFM = A-Z/W x 100%; where A = Weight of the obtained cake, Z = Weight of the wax, and W = Weight of the soap [16, 18].

Determination of total Alkali of the soaps

Soap (5.0 g) was weighed out and the water (100 mL) was added, it was dissolved well and heated directly (20-30 min). Then concentric sulfuric acid was added until fatty acid layer separate. Then chloroform (50 mL) was added and solution was added to the separation funnel. Separation funnel was shaken thoroughly until separate chloroform and fatty acid layers. Chloroform layer was separated, and aqueous solution was measured. Aqueous solution (10 mL) was taken to the titration flask and titrated against standard NaOH, methyl orange was added as an indicator. Then alkali content was determined using the obtained volume of NaOH. The total alkali was calculated using: % Total alkali = (VA-VB)/W × 100%; where, VA = volume of the acid used, VB= volume of the base, and W = weight of the soap [16, 18].

Results and Discussion

Some elemental composition of the MKO

Results of some elemental analysis of the MKO (mg/ 10g) revealed that Na, Mg, Cd, Ni, Zn, Mn were present; whereas, K, Pb, and Cu were not detected. Based on this composition, we found that MKO is rich in Na (162.59mg), Mg (10.077mg), and Mn (6.866mg); unlike Cd (0.062 mg), Ni (0.092 mg), and Zn (1.652 mg). Mg as an essential element plays a significant role in photosynthesis, carbohydrate metabolism, nucleic acids and binding agents of cell wall. It is also an essential mineral for enzyme activity, like calcium and chloride, magnesium also plays a role in regulating the acid – alkaline balance in the body [9]. However, the human body requires a small amount of Na to conduct nerve impulses, contract and relax muscles and maintain the proper balance of water and minerals. It is estimated that we need about 500mg of sodium daily for these vital functions. Manganese is a trace mineral. It is vital for the human body but required in small amounts. It contributes to many bodily functions, including the metabolism of amino acids, cholesterol, glucose and carbohydrates. It also plays a role in bone formation, blood clotting and reducing inflammation.

FTIR and UV characterization of the MKO

The MKO was also analysed for its FTIR absorption (see Fig. 1).The results showed absorption peaks of 2922.2-2855.1 cm^{-1} and 1744.4 cm^{-1} implied the presence of C-H stretch from saturated and unsaturated compounds and then ester/aldehyde/ketones/carboxylic acid, respectively. Asemave [19, 27] and Asemave *et al*. [28-31] reported similar evaluations of FTIR spectra. Furthermore, Reddy *et al*. [32] also confirmed the presence of C=O group at similar absorption values to the one reported in this work. UV absorption spectrum of the MKO revealed λ_{max} at 305 nm in n–hexane. The absorption band is in agreement with n-π* electronic transition most likely due to C=O functionality [39].

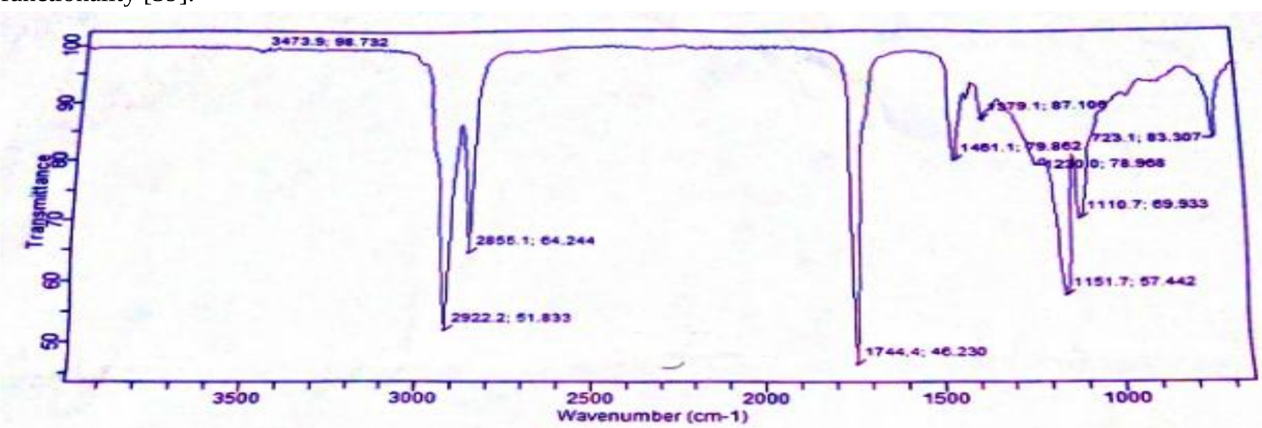

Figure 1: FTIR of the MKO

Masses of the soaps prepared

The soaps prepared at different compositions of MkO to CNO were obtained. CNO was chosen because it is a common saturated fat used to harden the soaps[16]. The masses of the soap obtained were similar and are shown in Figure 2 and Table 1 as follows. The yield of soap depends on the composition of oil used in soap making [26]. Furthermore, it was observed that the soap made using 100% MKO appeared to be brown, while that of 100% CNO was light -grey. The variation in appearances could be as a result of the degree of unsaturation of the fatty acids. Increase in double bonds causes increase in intensity of colour [5].

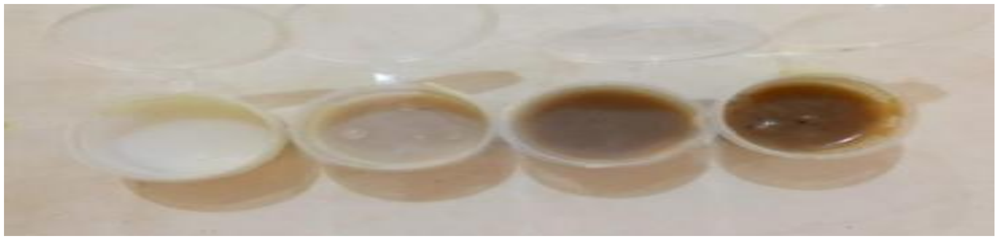

Figure 2: Four soaps prepared (i.e. in the ratio CNO:MKO); 100:0, 80: 20, 50:50, and 0:100, respectively from left to right

Table 1: Masses of the soaps prepared

Sample	Composition	Mass (g)
A	100% MKO	11.14
B	100% Coconut Oil	10.59
C	50% MKO and 50% Coconut oil	10.93
D	80% Coconut oil 20% MKO	10.20

Total Alkali, Total Fatty Matter, pH, and the foam height of the Soaps

The results for total alkali, total fatty matter, pH, and foam volume for the prepared soaps are given in Table 2.

Table 2: Total alkali, total fatty matter and pH and foam volume

Soap	Total Alkali %	Total Fatty Matter %	pH	Foam Volume (mL)
A	0.22	85.00	8.30	4.00
B	0.28	70.00	8.00	3.90
C	0.20	80.00	8.50	3.80
D	0.16	73.00	8.80	3.70
E	0.36	88.00	9.72	5.00
F	0.30	83.00	9.77	5.50

Sample A, B, C, and D contain MKO and CNO in the ratio 100:0, 0:100, 50:50 and 20:80, respectively; E and F are commercial soaps

The total fatty matter (TFM) of soaps was found to be 85%, 70%, 80%, 73%, 88%, and 83% for soap A, B, C, D, E, and F, respectively. Soap B (70%) and D (73%) have lower TFM which is due to the presence of unreacted NaOH in the soap formation. However, dry skin needs soap which is high in TFM to re-hydrate the skin making it smooth, and additionally the high oil content within the soap acts as a lubricant [18, 27]. According to International Standards (ISO), good quality soaps must have TFM above 76% [28]. In addition, acceptable TFM for toilet soap is between 76-77%, while that of laundry soap is between 45-50% [26]. Therefore, we can see that soaps from 100% MKO, 50% MKO: 50% CNO, and the two commercial soaps have excellent TFM (especially as toilet soaps), unlike soaps from 100% CNO and 80% CNO (i.e. better use as laundry soap). This in agreement with previous report that soaps made from coconut oil would dry the skin (would have lower TFM)[16]. Thus, to overcome that some conditioning and moisturizing components have to be added. Palm oil is another common saturated fat. Unsaturated fats are the best components for balancing saturated fats in a soap formula [16]. This again shows that MKO has higher unsaturated fatty acids as previously stated and should be a choice ingredient for balancing saturated fats in soap soaping. However different oils have different composition of fatty acids which are responsible for different properties of soaps made out of them.

Total alkali (TA) means the presence of total alkaline components such as hydroxides, carbonated, and bicarbonates in the finished soap. The obtained results for TA content of soaps are: 0.22%, 0.28%, 0.20%, 0.16%, 0.36%, and 0.30% for soap A, B, C, D, E and F, respectively. The results show that soap D showed lesser percentage of TA as compared to others[18]. These total alkali values are low and indicates that the soap formed will not be harsh on skin as soap with high alkali value causes skin itching and clothes wear out [29]. More so, the pH value observed for the MKO and CNO soaps prepared were between 8.00 – 8.80, while those of the two commercial toilet soaps were 9.72 and 9.77 for E and F, respectively. High pH (11 – 14)of soaps may be due to excess amount of lye used or incomplete hydrolysis; and can cause damage to skin [29]. Hence, soaps with pH values of 9 – 11 and 3 – 5 are considered as high and low levels, respectively by NAFDAC (a regulatory agency in Nigeria) [30]. The four soaps prepared were below the pH of 9; which is better and more friendly to our skin. In addition, the foaming ability of the MKO soaps in conjunction with the commercials soap were compared in terms of the foam height. Soaps A, B, C, D, E, and F had foam volume of 4.00 mL, 3.90 mL, 3.80 mL, 3.70 mL, 5.00 mL, and 5.50 mL, respectively (see Figure 3 below). The MKO and CNO soaps foam heights were lesser than those of the two commercial toilet soaps (E and F). This may be due to foaming additives in the toilet soap. Again, ability to produce foam well does not mean effective cleaning capability, though it is an interesting quality to users.

Foam volume of Soap A

Foam volume of soap B

Foam volume of soap C

Foam volume of soap D

Foam volume of E

Foam volume of F

Figure 3: Foam height of the soaps

Similarly, Hassan *et al*. reported the pH values of neem seed oil and Acacia nilotica seed oil soaps as 9.63 and 10.52, respectively. The soaps have total alkali values of 0.23 ± 0.20 and 0.85 ± 0.02 for neem oil soap and *Acacia nilotica* oil soap; with total fatty matter of 18.00 ± 2.00 and 7.33 ± 2.08, respectively. The foam height of the soaps were 2.37cm and 1.90cm for both neem oil soap and *Acacia nilotica* oil soap, respectively [18]. These properties are all comparable to the soaps of the MKO and CNO produced in this research, except for the TFM. Soaps made from MKO and CNO have acceptable TFM than those from neem oil soap and *Acacia nilotica* oil soap.

Cleaning properties

The soaps were tested for their ability to clean. The results of the cleaning ability are presented in Table 3 and Fig. 4 below.

Table 3: Cleaning ability of the soaps

Soap	Cleaning Properties
A	More Effective
B	Effective
C	effective
D	effective
E	Highly effective
F	Highly effective

Sample A, B, C, and D contain MKO and CNO in the ratio 100:0, 0:100, 50:50 and 20:80, respectively; E and F are commercial soaps

The cleaning efficiency of the soaps were determined by visual observations of the cleaning process of palm oil stains from filter papers. It was found that the commercial toilet soaps and the 100% MKO soaps were highly effective than the soap prepared with 100% CNO. This is possibly due to high content of stearic and oleic acid in MKO [2]. Previously, it has also been found that difference in the cleansing power of soap is due to the method use in the soap preparation and the nature of fatty acid composition of the fat or oil [26].

A drop of oil on filter paper | Cleaning ability of soap A | Cleaning ability of soap B | Cleaning ability of soap C | Cleaning ability of soap D

Figure 4: Cleaning ability of the soaps on from palm oil stains on filter papers

Conclusion

The MKO was extracted mechanically. The MKO was characterised and used in the preparation of soap along CNO. The analysis (using AAS) for elemental composition revealed that MKO has predominantly; Na (162.59 mg), Mg (10.077 mg), and Mn (6.866 mg). Meanwhile, the FTIR analysis of the MKO gave characteristics peak of 2922.2-2855.1 cm^{-1} and 1744.4 cm^{-1} implying the presence of C-H stretch from saturated and unsaturated compounds and then ester/aldehyde/ketones/carboxylic acid, respectively. The masses of the four soaps prepared using MKO and CNO in the ratio 100:0, 0:100, 50:50, 20:80, respectively were found to be 11.14 g, 10.59 g, 10.93 g and 10.20 g. Soaps from 100% MKO, 50% MKO: 50% CNO, and the two commercial soaps have excellent TFM (of 76% and above), unlike soaps from 100% CNO and 80% CNO (less than 76%). The soaps also indicated acceptable total alkali levels (of 0.16 – 0.36%). All the prepared soaps have lower pH values (less than 9) unlike the commercial soaps whose pH values were above 9. While the prepared soaps exhibited foam height of 4.00 mL, 3.90 mL, 3.80 mL, 3.70 mL for A, B, C, and D; the commercial soaps had foam heights of 5.0 mL and 5.50 mL, respectively for E and F. It was found that the commercial toilet soaps and the 100% MKO soaps were highly effective than the soap prepared with 100% CNO. This again shows that MKO should be a choice ingredient in soap soaping. This will consequently enhance use of MKO and prevent the littering of our environment with mango seeds/ kernels that often render it untidy.

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