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# Toilet Soap Formulation and Additives for Its Enhanced Physicochemical and Medicinal Properties

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***Abstract*—Human skin is an island in constant interaction between diverse microorganisms (Archaea, fungi, bacteria, and protozoa), especially the inner elbow, armpit and buttocks, of which an imminent health danger is possible during injury or their sustained proliferation. Fat-soluble lauric acid-containing palm kernel oil, hardness-giving caustic soda and water solvent were essential ingredients used to produce toilet soap in this study, via a mechanized setup. Free caustic alkali (FCA), pH and moisture content (MC), as determined for additive (honey, clove, black seed) formulations A, B, C, D and E, which are respectively in the range of 0.006-0.02%, 7.10-9.97, and 7.33-15.33%, gave a soap of desired medicinal functionality. Formulation E physicochemical property compares favorably with other soaps, including Septol, Dettol, Premier, Joy, Sunlight, and Premier Cool found in Nigerian markets. It is found that the three additives introduced into the formulation in the ratio of 33, 50 and 17%, respectively, are responsible for its septic, antioxidant, antimicrobial and sanitizing properties. With this fit achieved, improvement, packaging and mass production of the produced toilet soap already having satisfactory foam stability, lathering, cleansing, fragrance, form and quality (according to SNI standard), is encouraged in this part of the world.**

***Keywords*—Toilet soap, Soap additives, Saponification, Soap formulation, Palm kernel oil**

## I. INTRODUCTION

Toilet or bathing soap is uniquely manufactured to produce a luxurious lather via saponification process and be gentle on the skin, to be utilized for hand and body cleansing to maintain personal hygiene [1]. Soaps are made of three ingredients, namely; oil/fat (palm oil, palm stearin and lauric acid), lye (sodium hydroxide – NaOH and potassium hydroxide – KOH) and water (distilled, tap or deionized water) [2]–[5]. Many optional ingredients can be added to the 3 key ones for color, scent, texture, lather and antiseptic prowess. Users may notice soaps of different colors ranging from white, orange, yellow, red, green, brown, and purple [6], basically due to specific additives added to the soap formulation during production. For example, a soap consisting of the black walnut hull, ground cloves, allspice or nutmeg, will give a light dark brown color soap; yellow soap may consist of safflower powder, turmeric, annatto seeds and calendula petals; burdock leaf, comfrey leaf, dandelion leaf or French green clay will give a green soap; red soap are known to be as a result of its madder root, sandal wood powder and Moroccan red clay content and; alkanet root would likely create a purple soap. For quality control, fragrance strength after cure, fragrance discoloration, foamability, total fatty matter and foam stability test [7], need to be improved. A soap with inherent ability to kill germs when used on hand and skin is more beneficial, especially to minimize transmittable diseases caused by microorganisms [8, 9]. The assessment of soap physicochemical property had remained a tool to upgrade local and conventional soap quality and properties [5, 6, 10–14]. These properties include exposure risk (margin of safety, hazard index etc.), free caustic alkali (FCA, e.g., palmitic, stearic, oleic, lauric, myristic, linolenic & linoleic acid, etc.) [15], free fatty acid (FFA), antioxidant activity, alcohol insoluble matter, relative density, specific gravity, moisture content (MC), pH, swelling test, total dissolved solids, saponification value, iodine value, peroxide value, acid value, ester value, free carbonate alkali, hardness, conductance, total alkali content, chloride content and heavy metal composition. Hence, this study aims to produce toilet soap and evaluate its physicochemical properties and the impacts of additives addition on its quality. The study focuses on enhancing the health or skin influence of the soap by incorporating different medicinal additives, such as clove, black seed and honey into the soap formulation. It also involves the analysis of the soap texture, fragrance, pH level and cleaning effectiveness for improved quality. This study utilizes palm kernel oil and assesses only few


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physicochemical properties compared to a study by Osuji et al. (2013), Girgis (1999) and Doris (2024). Though sufficient for the present study, the properties will also be compared with obtainable soaps sold in Nigerian market, in a similar attempt by Gautam & Acharya (2023) and Betsy et al. (2013) in India, Mwanza & Zombe (2020) in Zambia, Vivian et al. (2014) in Kenya, Popescu et al. (2011) in Romania and Uduma et al. (2023), Idoko et al. (2018) and El-Ishaq & Anthonia (2020) in Nigeria. A thorough techno-economic analysis must be conducted to ascertain the feasibility of a large scale toilet soap production in any location [25, 26].

## II. MATERIALS AND METHOD

### A. *Choice of Materials*

Fat and oil soap ingredients naturally include rapeseed oil, rubber seed oil, avocado oil, apricot kernel oil, soybean oil, sunflower oil, olive oil, linseed oil, Aloe vera butter/oil, babassu nut oil, beeswax animal, borage oil, candelilla wax, canola oil, cherry kernel oil, jojoba seed oil, pumpkin seed oil, groundnut oil, mango seed oil, mustard oil, coconut oil, cocoa butter, cotton seed oil, shea butter, jatropha seed oil, castor seed oil, shea nut fat, neem seed oil, sesame seed oil, palm kernel oil and water plant seed oil [1, 11, 12, 15, 27], to mention a few, which affects the soap's hardness, cleansing ability and lathering. The palm kernel oil presented in Table 1 does the same, just like animal tallows [28, 29]. Palm kernel oil contains a fat-soluble lauric acid (or fatty acid), in which the presence of 10-15% produces quality soap [30]. Other materials used are displayed in Table 1, and were obtained in Maiduguri, Borno State, Nigeria.

**Table 1:** List of Major Toilet Soap Ingredients Used

| S/No. | Material | Quantity |
|---|---|---|
| 1. | Palm kernel oil | 8.5 L |
| 2. | Honey | 0.2 L |
| 3. | Black seed oil | 0.1 L |
| 4. | Clove | 0.3 kg |
| 5. | Caustic soda | 2 kg |
| 6. | Water | 4 L |

Caustic soda or sodium hydroxide (NaOH) interacts with fats and oils to transform them into soap molecules and glycerin, also acting as soap hardener [31]. Water serves as a vital solvent in the soap-making process, facilitating the saponification reaction by providing a medium for mixing and chemical transformation to occur. In this study, cloves, black seed oil and honey (Plate 1), serve as additive ingredients to enhance the soap physicochemical and medicinal properties.


**Plate 1:** (a) Clove (b) Honey and (c) Black Seed Oil Additives.

### B. *Soap Production Machines and Equipment*

Toilet soap production in this study involves the use of some machines and equipment. Adekunle et al. (2019) categorically stated that time, energy, material wastage and hazard are significantly reduced when machines are used. A saponification reactor (Plate 2a) was used to react the fat/oil with alkalis and the mixing tank helped in blending them with the additives. A beaker used in Uduma et al. (2023) may be likened to a reactor used herein. A heat source to achieve the desired temperature (60-70℃) and humidity was activated and a crusher (soap noodles machine – Plate 2b) grinds it into small and thin pieces called soap flakes or noodles. This process is called the hot process, where external heat application accelerates saponification and the rapid formation and use of the resultant hard soap (1 week after), as against cold process utilizing internal heat generated and taking longer time before use (4-6 weeks), according to Bruno (2023), Warra et al. (2010) and Kisuule (2022). Afterwards, an extruder/plodder shown in Plate 2c, was used to refine and homogenize the soap blend, remove


**Plate 2:** (a) Mixer (b) Crusher (c) Plodder and (d) Soap Cutter

air bubble and impurity and shape it to bars/pellets, before it is pressed to various shape and sizes using a soap stamper [11]. The pressed soap was then sliced into individual sizes using a soap cutter. After cutting (Plate 2d), soap bars need to be dried to reduce MC.

Drying racks or conveyors provide platforms for air-drying. Warra (2013) outlined similar steps in his study. Ab initio, the ingredients were prepared by pouring water into a container followed by gradual addition of lye (caustic soda). Careful stirring in a clockwise direction ensued until complete dissolution was achieved over a specified period, as shown in Plate 3a. Subsequently, the lye solution and palm kernel oil were combined in a mixer, allowing them to blend until reaching a creamy pudding-like consistency. Regardless of the stirring speed specified, rigorous mixing is desired via mechanical or manual means, especially in Kisuule (2022). As shown in Plate 3b, the mixture was spread out to dry on the ground. Once dried, the soap pallet underwent crushing in a crusher, ensuring the ingredients were thoroughly mixed in the appropriate proportions. This process continued until the desired range of pH, MC, and FCA, as specified in literature, was attained.


**Plate 3:** (a) Mixture of Caustic Soda, Water and Palm Kernel Oil, (b) Soap Pallet After Crushing and (c) the Soap Produced

Following this, the soap pallet was fed into a plodder, where it underwent refinement and homogenization to remove impurities and air bubbles. Finally, a soap cutting device was utilized to cut the soap into individual sizes and shapes shown in Plate 3c. The whole process may be summarized by the diagram in Figure 1.

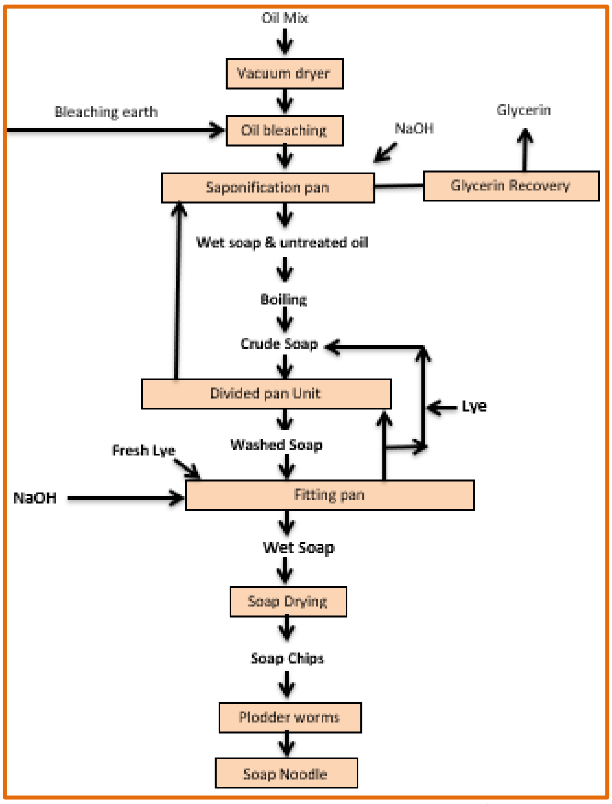


**Figure 1:** Typical Soap Production Flowchart in a Manufacturing Plant.

### *C. Quality Test*

During toilet soap manufacture, various quality tests were carried out to see if the soap produced, adheres to industry standards and retains its intended characteristics. These tests serve to assess the soap's efficacy, safety and overall quality.

#### *C.1. Soap pH*

pH strips or meter was used in such a way that 10% soap solution was prepared by dissolving 15g of soap shavings in distilled water within a 100 $cm^3$ volumetric flask. Subsequently, the solution was left undisturbed overnight to ensure complete dissolution of the soap. The pH was then measured using a pH meter on the subsequent day, in accordance with the procedure followed in Gautam & Acharya (2023), Asemave & Edoka (2021) and Uduma et al. (2023). Soap formulations with pH levels outside the acceptable range may provoke skin irritation or dryness [31].

#### *C.2. Moisture Content*

The MC of the soap, which impacts its stability and shelf life, was assessed by drying a 15g sample until a constant weight was achieved at 105ºC, following the procedure outlined in AOAC 2000 [17]. The dried sample was then allowed to cool before reweighing it. The MC was then determined using Equation 1 or IS 286:1978 standard [1, 6, 23, 36],

$$\mathrm{MC} = \frac{\mathrm{M_s} - \mathrm{M_h}}{\mathrm{M_s} - \mathrm{M_w}} \times 100 \quad (1)$$

where, $M_w$ = weight of the container, $M_s$ = weight of container + sample and $M_h$ = weight of container + sample after heating.

*C.3 Appearance and Odor Evaluation*

Visual inspection was carried out to evaluate the soap's appearance, encompassing factors such as color, shape and surface texture. Any deviations such as discoloration, spots, or irregularities were noted, as they may signify flaws in the manufacturing process or ingredient quality. Additionally, the soap's fragrance was assessed to confirm its adherence to the intended scent profile and consistency across the product.

*C.4. Cleaning Properties*

Used oil droplets were deposited onto strips of filter paper, as reported in Owoicho (2021), which were subsequently immersed in bottles containing 1% soap solutions. After vigorous shaking and a resting period of 2 min, the filter paper was extracted and rinsed with water. The effectiveness of cleansing was then visually assessed and documented.

*C.5. Foam Stability and Lathering*

About 1% of the soap samples were prepared and equal amount of the soap solution was measured into a bottle. It was shaken vigorously for 1 min and allowed to stand for another 5 min, after which the height of the foam was observed and recorded, in accordance with Owoicho (2021b). To assess the soap's lathering, a small amount of the dry soap was used to wash the hands using deionized water. The lathering properties (i.e., very slippery, greasy or about normal) and the "feel" of the soap were taken [39].

*C.6. Determination of Free Caustic Alkali Level*

Girgis et al. (1998), Vivian et al. (2014) and the American Oil Chemists Society (AOCS) outlined protocol was used in the determination of FCA. In the method, 5g of the finished soap was accurately weighed and dissolved in 30 mL of ethanol. A few drops of phenolphthalein indicator were introduced, followed by the addition of 10 mL of 20% barium chloride ($BaCl_2$) solution. The resulting mixture was titrated against 0.05M aqueous sulphuric acid ($H_2SO_4$). Finally, the volume of the acid consumed in the titration was calculated using Equation 2 [1, 6, 20, 36],

$$\mathrm{FCA} = 0.31 \times \frac{\mathrm{V_a}}{\mathrm{W}} \quad (2)$$

where, $V_a$ is the acid volume and W represent the weight of the soap.

## III. RESULTS AND DISCUSSION

*A. Measured Physicochemical Properties*

Table 2 show that the physiochemical properties of the produced soap compare favorably with conventional soaps sold in the market. Habib et al. (2016) reported an MC = 10.97%, pH = 9.68-9.79 and 0% FCA for Dettol soap, in close agreement with the one assessed in this study. But the Bangladeshi type of Dettol soap is considered more basic than the one sold in Nigeria and the one reported by Zol & Rus (2023).

MC is the amount of free water present in the soap, crucial for determining its shelf life. Excessive water content in soap can lead to hydrolysis of unreacted triglycerides, affecting soap quality and reducing shelf life.

**Table 2:** Physicochemical Properties of the Soap Produced in Comparison to Other Soaps

| S/No. | Sample | MC (%) | pH | FCA (%) |
|---|---|---|---|---|
| 1. | This Study | 15.33 | 9.97 | 0.02 |
| 2. | Septol | 18.72 | 9.96 | 0.12 |
| 3. | Dettol | 7.70 | 10.17 | - |
| 4. | Premier | 15.94 | 10.40 | 0.06 |
| 5. | Joy | 11.96 | 10.10 | 0.08 |
| 6. | Sunlight | 13.24 | 9.85 | 0.06 |
| 7. | Premier Cool | 14.14 | 9.93 | 0.02 |

Shelf life can be improved using wild berries [40]. The MC obtained after the analysis was 15.33%, within the recommended range of 10 – 20% [24, 41], indicating that microbial growth is unlikely to be favored. This is in agreement with Doris (2024) who obtained an MC = 13% using palm kernel oil. Some country's standard is for example an MC < 0.3% mentioned in Girgis et al. (1998). It is obvious that pH is significant in determining soap quality, with values < 5 or > 10, said to be associated with skin hardness. Soap, being a salt of weak acid and base, is naturally alkaline in aqueous solution, and a pH above 7 (Figure 2) is generally expected. Atiku et al. (2014), Oyigye (2021), Doris (2024), Onyegbado et al. (2002) and Okunola et al. (2019) previously analyzed the use of industrial and locally made alkali. Thus, a pH = 9.97 obtained in this study, falls within the recommended range of 7-10 reported in the literature [44]. FCA affects soap abrasiveness and a value of 0.02 % is well below the standard value of 5%. This indicates that the soap will not be harsh on the skin. In consonance with this study (0.02-0.12%), Kuntom et al. (1996) obtained a value between 0.02-0.09% for palm kernel oil utilization. Figure 2 depicts the pH and % MC of the Nigerian soaps or those found in the country.

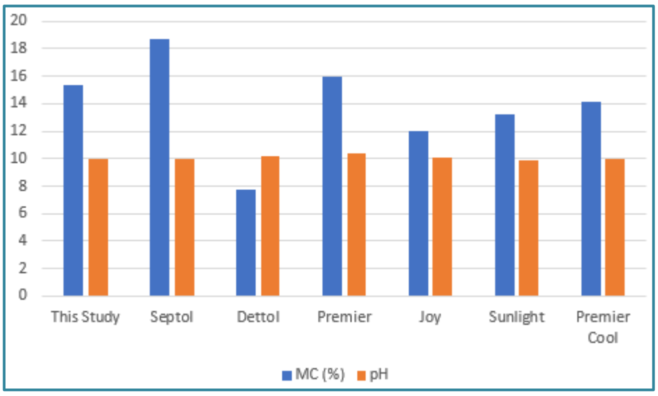


**Figure 2:** Moisture Content and pH of the Prepared Soap and Other Soap

El-Ishaq & Anthonia (2020) also studied several of these toilet soaps found in Nigeria, namely Lux, Olive, Imperial, Carex, Zee, Hala, Needz and Eva for foam height, hardness, foam time and % matter insoluble in ethanol, without comparing their pH and MC. Idoko et al. (2018) compared pH, FCA, MC, total fatty matter and matter insoluble in alcohol, amongst Safeguard, Tetmosol, 4B, MP3, Sunlight, Leather, Glide and Canoe soaps.

*B. Effect of Additives*

Five other additive formulations or combinations tagged A, B, C, D and E were studied. Essentially, the effect of different additives on some properties of the soap produced,

**Table 3:** Soap Formulation Based on Different Additives Ratio and their Properties

| Combination | Honey (L) | Clove (kg) | Black seed (L) | pH | MC (%) | Free Alkali |
|---|---|---|---|---|---|---|
| A | 0.04 | 0.06 | 0.02 | 7.10 | 7.33 | 0.006 |
| B | 0.08 | 0.12 | 0.04 | 7.98 | 9.33 | 0.009 |
| C | 0.12 | 0.18 | 0.06 | 8.60 | 10.66 | 0.013 |
| D | 0.16 | 0.24 | 0.08 | 9.05 | 13.33 | 0.017 |
| E | 0.20 | 0.30 | 0.10 | 9.97 | 15.33 | 0.020 |

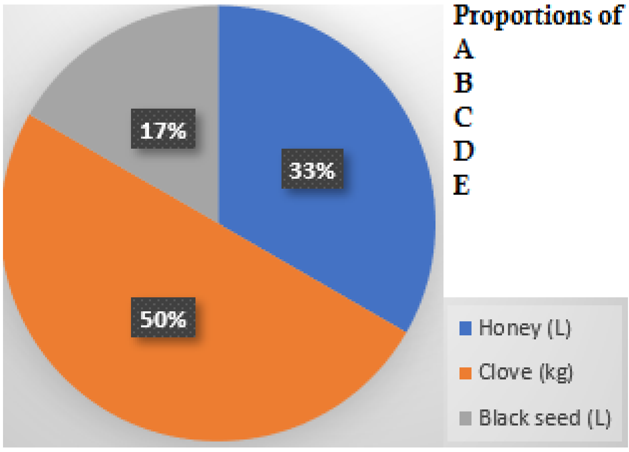


**Figure 3:** Equal Ratio Additive Formulation

as showcased in Table 3 were studied. Figure 3 illustrates the ratio or proportion of this additive's addition for each formulation. Generally, it is observed that higher concentrations of the natural additives (Table 3), amplified their effects, impacting the soap's pH, MC and FCA levels. Honey, known for its moisturizing properties, enhances the soap's hydration and it is also known to give the soap a sanitizing effect [31]. Clove, with its antimicrobial properties due to its eugenol constituent [46], imparted a pleasant sent to the soap and gives it a brown color. Onyegbado et al. (2002) mention the realization of a yellow-colored soap from palm-bunch waste. Black seed, rich in antioxidants, provided skin care benefits to the soap. When compared to other soap variations, it becomes evident that the produced soap exhibits high quality, making it safe for use. Mwamba et al. (2024) discovered that the limonene content in citrus peel had antimicrobial effect when used as additive, in a similar fashion with black seed and clove. The combination of natural additives such as honey, clove, and black seed (33, 50 & 17% mixture, respectively) resulted in a soap with unique characteristics. This soap holds potential benefits for the skin due to the distinctive properties of these natural additives. Other important additives that would enhance soap antibacterial and antioxidant activity are date-fruit syrup [47], rose petal, yam root, betel leaf and noni fruit [48]. It is observed in Figure 4 that the properties measured are highest in formulation E, even though all are acceptable formulations.

Triclosan and sodium lauryl sulfate (SLS) are active synthetic ingredients that may harm the skin [49], and hence must be avoided.

### C. *Cleansing Effectiveness*

It effectively removes dirt, oil, and impurities while preserving or even enhancing the skin's natural balance and comfort. It demonstrates normal washing properties by efficiently and thoroughly cleaning various surfaces and items, effortlessly lifting dirt, stains and grease.

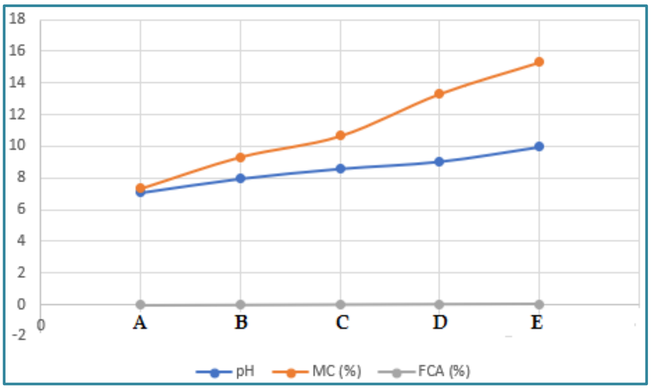


**Figure 4:** Properties of the Respective Combinations

Moreover, it exhibits very stable foam and lathering properties, producing a rich and luxurious lather when used. Upon contact with water, the soap effortlessly transforms into a creamy, indulgent foam that extensively covers the skin or surface, ensuring thorough cleaning. Oyigye (2021) described a similar behavior of the soap he obtained from agricultural waste ash alkali and palm kernel oil mixture. For enhanced therapeutic, prophylactic and antiseptic effects of toilet soap [50], factors affecting the effective cleansing ability of several formulations and additive amounts towards finding the optimum combination, should be investigated. Mohammed & Usman (2018) described the physicochemical soap analysis as a tool to determine soap quality and cleansing efficacy. For example, foaming efficiency can be enhanced by adding water softeners and scum dispersant, as it lowers the surface tension of the water [51].

## IV. CONCLUSION

In this project, the quality of the soap produced with varying concentrations of natural additives was successfully assessed, where parameters such as pH, MC and FCA evaluated, demonstrated satisfactory soap quality characteristics within acceptable ranges. It was found that the inclusion of honey, clove, and black seed in soap production had discernible effects on the soap's properties. These natural additives contributed to moisturizing, antimicrobial and antioxidant properties, enhancing the overall quality and potential benefits of the soap. The combination of natural additives resulted in a soap with unique characteristics, including improved moisturization, pleasant scent and skincare benefits. For instance, honey is known to contain secondary metabolites, namely alkaloids, flavonoids, tannins, and saponins, which have antibacterial and anti-free radical activity. This suggests that the incorporation of such additives can add value to soap formulations and provide additional benefits to consumers. To implement a mass scale production, additional research to optimize the concentrations and combinations of natural additives for maximum efficacy in soap formulations is necessary. Evaluation of consumer preferences and market demand for soaps with natural additives, to determine the potential for commercialization and market penetration is also important.

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CONFLICT OF INTEREST

Authors declare that they have no conflict of interest.

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