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Research Article

Physicochemical Quality Evaluation of Commercial Soaps Marketed in North Western Nigeria

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Abstract

This research evaluated the physicochemical properties of selected commercial soaps sourced from prominent markets in north-western Nigeria. A total of forty soap samples including toilet, laundry, medicated, and multipurpose soaps, were randomly acquired from central markets located in Katsina State, Kano State, Kaduna State, and Jigawa State. The samples were transported to the laboratory, grated and underwent physicochemical analysis following standard analytical methods. The parameters assessed included total fatty matter(TFM), alcohol insoluble matter(AI), free alkali(FA), pH, moisture content(MC), and hardness(Hdn). Total fatty matter values were found to range from 54.13% to75.36% in toilet soaps, 45.38% to76.09% in laundry soaps, 68.32% to 78.55% in medicated soaps, and 58.46% to 76.09% in multipurpose soaps. Several samples met or surpassed the recommended limits set by the Standards Organisation of Nigeria. However, some products displayed high levels of alcohol insoluble matter and free alkali, which could potentially impact product quality and skin compatibility. The pH values varied from 6.45 to 9.58, indicating a range from mildly acidic to strongly alkaline, with several samples exceeding the recommended pH range for skin-friendly soaps. Moisture content and hardness also exhibited significant variation among the samples analyzed. Analysis of variance (ANOVA) revealed no significant differences ($p>0.05$) among the soap categories concerning the measured physicochemical parameters. Correlation analysis demonstrated a strong negative correlation between TFM and AI ($r=-0.619$, $p<0.01$), indicating that higher fatty matter content was associated with lower levels of insoluble materials. Additionally, moisture content showed a very strong positive correlation with hardness ($r=0.947$, $p<0.01$), while moderate positive correlations were noted between pH and other parameters.

Keywords

Soaps, Physico-chemical Parameters, Multi-purpose, Laundry, Medicated

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1. Introduction

Back ground of the Study

The quality of commercial soaps in North-western Nigeria shows quite a bit of variation, with many not meeting the required standards. To tackle this issue, there is need to enforce regulatory standards more strictly, educate consumers about the importance of buying from trust worthy sources, and support local manufacturers who are dedicated to producing quality products [1]. Making soap involves a reaction between vegetable oils and / or animal fats with either sodium hydroxide or potassium hydroxide [2]. This process, known as "saponification," breaks down triglycerides using a base (usually NaOH or KOH) to create three salts (soap) and glycerol. The type of base used can influence how the molecules crystallize. KOH is typically preferred for liquid or soft soaps, while NaOH is better for creating a firmer bar [3].

$$\text{Oil} + 3\text{NaOH} = \text{Glycerol} + 3\text{Soap} \quad (1)$$

Soap is essentially a compound made from fatty acids that have been mixed with salt. Each soap molecule features a long hydrocarbon chain with a carboxylic acid group at one end, which forms anionic bond with a metal ion, typically sodium or potassium [4]. The ionic part loves water, making it soluble, while the hydrocarbon end is non polar and prefers non polar substances. This unique structure allows soaps to emulsify or suspend insoluble materials in water, making them effective cleaners [5]. From a chemical stand point, soap is an alkali metal salt derived from long-chain mono carboxylic acids, serving as a cleaning agent. It's often represented by the formula CH_3COONa, where CH_3COONa indicates the polar group, and R represents the hydrocarbon chain [6]. For soaps to be effective, they typically have a hydrophobic carbon chain ranging from 12 to 18 carbon atoms. As noted by [7], if the hydrophobic part has fewer than 12 carbon atoms, it struggles to remove oil; conversely, if it has more than 18 carbon atoms, it behaves more like a deter gent, although the term "detergent" is generally reserved for synthetic versions. In essence, soap is a widely used cleaning agent that can come in various forms—granules, bars, flakes, or liquids—created by reacting sodium or potassium salts with natural fatty acids [8].

Soap can be described as any water-soluble salt made from fatty acids that have eight or more carbon atoms. It's produced for a range of uses, such as washing, bathing, and even for medicinal purposes [9]. The main reason soap is being use with water for cleaning is that the hydrocarbon chain loves to bond with oil and grease, while the carboxylic group is more compatible with water [10]. Several factors influence the process and quality of soap, including the type of oil, the amount of caustic soda, and the water content [4].

The interaction rate between the oil and caustic soda is affected by the free fatty acid content of the oil and how vigorously the mixing is done. Heat, quick mixing, and the presence of free fatty acids all help speed up the soap-making process [11]. The physicochemical properties of soaps play a crucial role in determining their quality and effectiveness in washing. These properties include pH, moisture content, free fatty acids, total fatty matter, free caustic alkali, and hardness [12].

To enhance the quality of the soap, additional chemicals are often included in the mix. For example, when creating medicated soap, extra medicinal ingredients are added for therapeutic use [4]. Besides potassium and sodium salts, other metals like calcium, magnesium, and chromium are used to create metallic insoluble soap, which serves purposes beyond just cleaning. The type of metallic element in the salt also influences other characteristics of the soap, such as its hardness [13].

When the same type of fat or oil is used in both cases, soap made from sodium salts tends to be harder than soap made from potassium salts. This is different from soaps made with divalent metals like calcium, magnesium, aluminum, or iron, which don't dissolve in water. Soaps are commonly used for laundry and cleaning, and interestingly, calcium soap has even been noted as an ingredient in animal feed [7]. Typically, triglycerides—essentially fats or oils—are transformed into soap through a process called saponification. During this process, when triglycerides react with a strong alkali like potassium or sodium hydroxide, glycerol and fatty acid salts are produced [14]. The term "soap" refers to these fatty acid salts. The following equations show the typical reactions involved in saponification:

$$C_3H_5(OOCR)_3 + 3KOH3KOOCR + C_3H_5(OH)_3 \quad (2)$$

Fat Potassium hydroxide Soap Glycerol

or

$$C_3H_5(OOCR)_3 + 3NaOH3NaOOCR + C_3H_5(OH)_3 \quad (3)$$

Fat Sodium hydroxide Soap Glycerol

Physicochemical parameters refer to the physical and chemical properties of a substance that influence how it behaves and performs. These parameters help describe various characteristics, including electrical and thermal properties. In the realm of soap analysis, physicochemical parameters encompass aspects like pH, total fatty matter, moisture content, free alkalinity, penetration value, hardness, lather volume, and lather stability. All of these factors are crucial for assessing the soap's performance, quality, and safety. Consequently, this study zeroes in on the physicochemical analysis of selected soaps available in states within the north west geopolitical zone.

2. Materials and Methods

2.1. Study Area

Katsina State occupies an area of 29,938 km^2 lying between

latitude 11 °7'N and 13 °32'N and longitude 6 °52' and 9 °02". Kaduna state lies between latitude 10 °26'N to 10 °40'N and longitude 7 °19'E to 7 °33'E. Kano state also lies between latitude 11 °55'N and 12 °3'N and longitude 8 °27'E to 8 °36 E, having an elevation of 472m above sea level. Jigawa state has a location of 10 °N and 12 °N and a longitude of 7 °E and 10 °E, which covers an approximate land area of about 22,410km^2. The map of the study area is demonstrated in Figure 1 below.

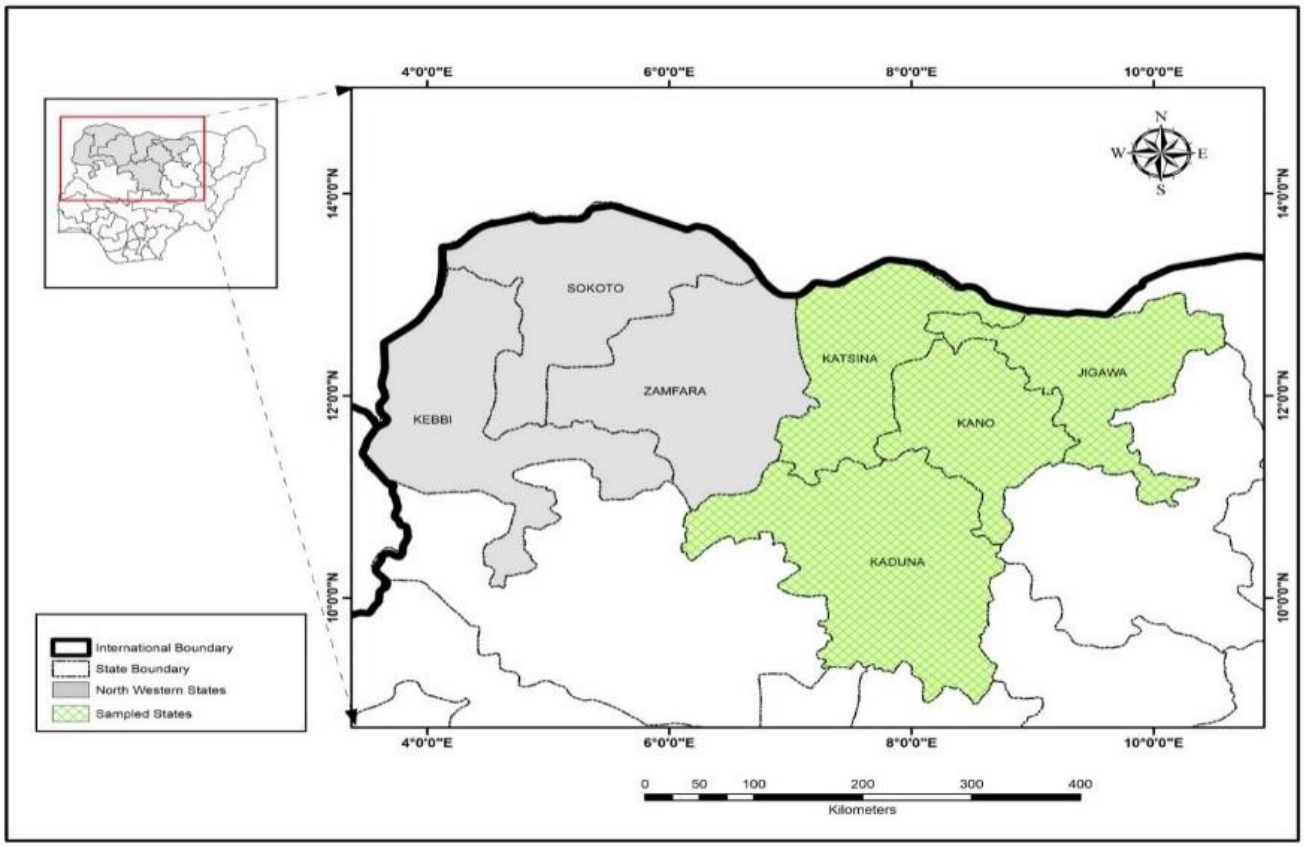


Figure 1. *Map of the study area.*

2.2. Sample Collection and Processing

The medicated, laundry, multipurpose, and toilet soaps were obtained from Katsina, Kano, Kaduna, and Jigawa Central Markets, north-west geopolitical zone Nigeria. All the samples (40soaps) were randomly collected and aseptically transported to Umar Musa Yar'adua University Central laboratory for analysis [15]. Each soap sample was finely grated using a sterilized grater, and was placed in cleaned plastic container until further used [3].

2.3. Physicochemical Analysis

2.3.1. Moisture Content

Moisture content was determined as described by [16]. The granulated sample, 5.0g was weighed in a dried crucible and place in the oven at 103˚C for 2hrs 30mins. The crucible plus sample was allowed to cool in desiccators and then re-weighed. The percent moisture content was determined by employing equation (1):

$$\%\text{Moisture content} = \frac{Cs-Ch}{Cs-Cw} \times 100$$

Where;
Cw= weight of the crucible
Cs=weight of crucible + sample
Ch=weight of crucible + sample after oven drying.

2.3.2. pH

The pH was determined as described in [17]. The granulated soap (2.0g) was dissolved in 20ml distilled water to make a 10% soap solution. Then the solution was left to stand overnight to allow the complete dissolution of soap. The pH was calibrated using a buffer solution. All the soap samples pH was measured with a pH meter on the following day.

2.3.3. Total Fatty Matter

Total fatty matter was determined as described in [18]. The sample (5.0g) was weighed and in an empty crucible and a 100ml of ethanol (50%v/v) was added. Then the mixture was

heated on the water bath until the entire sample has been dissolved and while the solution is still hot, a 40ml 0.5 Normal nitric acid was added and shook vigorously. The solution was left to cool at room temperature and the resulting substance was weighed in order to calculate the total fatty matter using equation (2) below:

$$\%Total fatty matter = \frac{Y-X}{Ws} \times 100$$

Where:
Y= weight of crucible + sample after evaporation
X= weight of empty crucible
Ws= weight of sample

2.3.4. Free Alkali

Free alkali was determined as in [19]. The sample (2.5g) was dissolved in 15ml distilled ethanol and heated in the water bath until the sample had completely dissolved. This was then followed by addition of 5 drops of phenolphthalein indicator and 5ml of 20% $BaCl_2$. The resultant solution was titrated against 0.05M H_2SO_4 in order to neutralize the sodium hydroxide, NaOH present to the disappearance of pink colour. The free caustic alkali was calculated using equation (3):

$$\% \ \ freeAlkali = \frac{0.31 \times Va}{W}$$

Where;
Va= volume of acid
W= weight of sample

2.3.5. Alcohol Insoluble

To analyze the soap sample, we started with 5.0g, which was dissolved in 50mL of alcohol. This mixture was then carefully transferred to a pre-weighed filter paper. After that, the residue was dried in an oven at 105 ℃ for 30minutes, cooled in desiccators, and weighed again [20]. We calculated the amount of insoluble matter in alcohol (MIA) using equation, (4), as out lined by [21].

$$\%\text{Alcohol Insoluble Matter} = (Ws - FP)/W \times 100$$

Where:
Ws is the Weight of the sample + filter paper,
FP is the Weight of the filter paper, and
W is the Weight of the sample.

2.3.6. Hardness (Penetration Value)

To test the hardness of the soap, we used a needle to pierce the surface. The depth to which the needle penetrated the soap bar indicated its hardness [22].

2.4. Statistical Analysis

The data collected from the study were analysed using the Statistical Package for Social Sciences (SPSS, Version20). Descriptive statistics were employed to summarize the data, while correlation analysis helped us understand the relationships among the different parameters. Also ANOVA was used to determine any significant differences in the soaps across various states within the geopolitical zone.

3. Results

Tables 1 through 6 resent the mean and standard deviation values for laundry, toilet, multipurpose, and medicated soaps, along with their corresponding reference values from the Standards Organisation of Nigeria(SON). Physicochemical characterizations of the different soaps was conducted which include TFM, AI, FA, pH, moisture content(MC), and hardness(Hdn), as well as their microbial analysis.

Table 1 displays the mean and standard deviation values for key parameters of the toilet soap samples (T_1–T_{10}). The parameters evaluated include total fatty matter(TFM), alkali insoluble(AI), free alkali(FA), pH, moisture content(MC), and hardness(Hdn). Additionally, standard values provided by standard organization of Nigeria (SON) was used for comparison.

The TFM content ranges between 54.13 ±0.31(T_2) and 75.36 ±0.52(T_1), with most samples meeting or exceeding the SON recommended range of 50-65. The AI varies widely, from as low as 0.85 ±0.08(T_1) to 34.33 ±0.45(T_2). High AI values, such as in T_2 andT_4, may indicate the presence of unreacted alkali, which could lead to skin irritation. All samples have FA values within the acceptable limit of 0.1 specified by SON. The FA is minimal, with values ranging from 0.02 ±0.01(T_1) to 0.16 ±0.01(T_2), suggesting minimal residual alkali and good saponification. The pH values of the soap samples range between 6.60 ±0.08(T_9) and 9.58 ±0.05(T_6), mostly falling within the SON- recommended range of 6.5 – 8.5. MC content varies significantly, with the highest observed in T_6(12.57 ±0.05) and the lowest in T_{10}(7.01 ±0.01). The hardness values range from 4.50 ±0.58(T_2) to 10.00 ±0.00(T_3), indicating varying degrees of soap firmness.

Table 1. *Mean and standard deviation values for toilet soap.*

Sample	TFM%	AI%	FA%	pH	MC%	Hdn(mm)
T_1	75.36 ±0.52	0.85 ±0.08	0.02 ±0.01	7.33 ±0.09	11.95 ±0.17	8.00 ±0.82

Sample	TFM%	AI%	FA%	pH	MC%	Hdn(mm)
T_2	54.13±0.31	34.33±0.45	0.16±0.01	9.08±0.09	5.22±0.15	4.50±0.58
T_3	70.37±0.43	7.99±0.16	0.14±0.01	9.5±0.12	12.22±0.20	10.00±0.00
T_4	63.57±0.29	22.0±0.11	0.04±0.01	6.63±0.05	8.15±1.21	6.00±0.00
T_5	72.00±0.03	7.28±0.03	0.13±0.01	9.08±0.08	11.99±0.03	7.00±0.00
T_6	62.01±0.43	11.64±0.73	0.15±0.01	9.58±0.05	12.57±0.05	8.50±0.85
T_7	70.56±0.54	7.74±0.05	0.14±0.01	9.00±0.00	12.10±0.12	8.25±0.50
T_8	60.85±0.11	20.16±0.03	0.08±0.01	8.58±0.30	7.02±0.02	5.25±0.50
T_9	63.46±0.38	22.00±0.04	0.04±0.01	6.60±0.08	7.16±0.40	6.00±0.00
T_{10}	59.90±0.08	19.51±0.01	0.10±0.01	7.55±0.06	7.01±0.01	7.00±0.00
SON	50-65	15.6	0.1	6.5-8.5	25.0	-

Key: T_1-Lux, T_2-Hala, T_3-F/Glow, T_4-Premier, T_5-Nova, T_6-Siri, T_7-Eva, T_8-S/Aloe, T_9-F/Care, and T_{10}-Safeguard

Table 2 show cases the average and standard deviation values for various quality parameters of laundry soap samples(L_1–L_{10}). These parameters include Total Fatty Matter(TFM), Alkali Content(AI), Free Alkali(FA), pH, Moisture content(MC), and Hardness(Hdn), with standards set by the SON(Standards Organisation of Nigeria) for reference. The TFM content varies from 45.38±0.28(L_3) to 76.09±0.08(L_9). According to SON, the acceptable range is between 70 and 76, and samples like L_2, L_6, L_7, L_9, and L_{10} either meet or surpass this standard, suggesting they have better cleaning capabilities. On the other hand, samples with lower TFM, such as L_1, L_3, and L_4, might not clean as effectively. The AI values show quite a range, from a lo w of 0.11±0.01(L_6) to a high of 29.20±0.24(L_3), with most samples exceeding the SON limit of 3.0. FA levels range from 0.06±0.01(L_2andL_4) to 0.19±0.04(L_1). The SON limit for FA is set at 0.1, and only samples L_2, L_4, and L_6 fall within this limit. The pH values of the soaps range from 7.20±0.24(L_5) to 9.48±0.10(L_1). While SON recommends a pH range of 6.5–8.5, samples like L_1 and L_3 exceed this, which could make them to alkaline for everyday use. The MC values fluctuate between 14.63±0.02(L_5) and 20.36±0.25(L_1), with most samples above the SON limit of 13.0. Lastly, hardness values range from 14.00±0.00(L_7) to 18.75±0.50(L_3), showing some differences in firmness.

Table 2. *Mean and standard deviation values for laundry soap.*

Sample	TFM%	AI%	FA%	pH	MC%	Hdn(mm)
L_1	58.46±0.50	16.21±0.25	0.19±0.04	9.48±0.10	20.36±0.25	18.50±0.58
L_2	71.89±0.34	0.88±0.02	0.06±0.1	8.00±0.08	16.22±0.35	18.00±0.81
L_3	45.38±0.28	29.20±0.24	0.17±0.01	9.30±0.08	19.80±0.28	18.75±0.50
L_4	57.82±0.15	18.00±0.11	0.06±0.01	8.00±0.08	16.20±0.35	18.00±0.82
L_5	63.75±0.32	15.84±0.42	0.08±0.01	7.20±0.24	14.63±0.02	15.00±0.00
L_6	70.42±0.16	0.11±0.01	0.07±0.01	8.53±0.05	15.56±0.08	18.25±0.50
L_7	73.28±0.15	14.52±0.55	0.07±0.02	7.95±0.06	14.73±0.32	14.00±0.00
L_8	65.44±0.26	14.10±0.62	0.11±0.01	8.03±0.05	15.59±0.28	17.00±0.00
L_9	76.09±0.08	13.45±0.44	0.15±0.01	8.75±0.29	16.40±0.04	15.25±0.50
L_{10}	75.80±0.01	16.22±0.03	0.18±0.03	8.38±0.25	16.25±0.16	14.75±0.50
SON	70-76	3.0	0.1	6.5-8.5	13.0	-

Key; L_1-Waw, L_2-Vplus, L_3-Nittol, L_4-Suban, L_5-Manuka, L_6-Mamuda, L_7-2lemon, L_8-Caneo, L_9-2sure, and L_{10}-VL+

Table 3 show cases the average and standard deviation values for important parameters of medicated soap samples (M_1–M_{10}). The Total Fatty Matter (TFM) content varies from 68.32 ±0.22(M_8) to 78.55 ±0.36(M_3). According to SON guide lines, the ideal range is between 70 and 76. Most samples fit within this range, except for M_3, which goes over the limit, and M_8, which falls short. The AI values show a wide range, from 0.87 ±0.11(M_1) to 16.66 ±0.08(M_6), with only M_1, M_4, and M_8 meeting the SON threshold of 3.0. FA values span from 0.02 ±0.01(M_3 and M_4) to 0.47 ±0.02(M_{10}), while the SON –recommended maximum is 0.05. The pH levels range from 6.45 ±0.06(M_6) to 9.08 ±0.05(M_5). Although most samples are within the SON range of 6.5 to 8.5, M_5 exceeds the upper limit. MC values fluctuate between 3.74 ±0.10(M_3) and 9.99 ±0.07(M_4). The SON limit is set at 5.0, and samples like M_1, M_3, M_5, M_6, and M_9 are compliant. Lastly, the hardness values range from 2.00 ±0.00(M_3) to 7.75 ±0.50(M_4).

Table 3. *Mean and standard deviation values for medicated soap.*

Sample	TFM%	AI%	FA%	pH	MC%	Hdn(mm)
M_1	71.66 ±0.53	0.87 ±0.11	0.03 ±0.01	7.65 ±0.10	5.17 ±0.57	4.00 ±0.00
M_2	74.61 ±0.56	5.72 ±0.06	0.11 ±0.01	8.28 ±0.05	7.77 ±0.11	6.25 ±0.50
M_3	78.55 ±0.36	7.15 ±0.14	0.02 ±0.01	7.60 ±0.00	3.74 ±0.10	2.00 ±0.00
M_4	76.20 ±0.11	3.72 ±0.06	0.02 ±0.01	7.60 ±0.05	9.99 ±0.07	7.75 ±0.50
M_5	70.07 ±0.01	16.36 ±0.05	0.12 ±0.01	9.08 ±0.05	4.11 ±0.11	3.00 ±0.00
M_6	70.53 ±0.34	16.66 ±0.08	0.23 ±0.01	6.45 ±0.06	4.37 ±0.05	3.00 ±0.00
M_7	72.51 ±0.55	13.93 ±0.55	0.13 ±0.01	6.75 ±0.06	4.75 ±0.05	3.25 ±0.50
M_8	68.32 ±0.22	1.10 ±0.10	0.25 ±0.02	6.63 ±0.05	6.36 ±0.15	5.50 ±0.58
M_9	74.73 ±0.07	15.71 ±0.20	0.28 ±0.02	6.70 ±0.00	4.53 ±0.02	4.00 ±0.00
M_{10}	73.22 ±0.02	14.85 ±0.10	0.47 ±0.02	6.90 ±0.00	6.10 ±0.04	5.00 ±0.00
SON	70-76	3.0	0.05	6.5-8.5	5.0	-

Key; M_1-B/Septol, M_2-Delta, M_3-Sanitol, M_4-Septol, M_5-D/Even, M_6-D/Cool, M_7-DettolA, M_8-2sure, M_9-Dosun, and M_{10}-Tetmosol.

Table 4 show cases the average and standard deviation values for the quality parameters of various multipurpose soap samples (Mp_1–Mp_{10}). The Total Fatty Matter (TFM) values range from 58.46 ±0.49 for Mp_3 to 76.09 ±0.09 for Mp_2. Soaps with higher TFM values, like Mp_2, Mp_6, and Mp_5, are known for their better cleansing and moisturizing abilities. The Alcohol Insoluble (AI) values fluctuate between 0.88 ±0.02 for Mp_1 and 16.29 ±0.20 for Mp_{10}. Only Mp_1 falls below the ideal AI threshold of 3.0, suggesting it's the safest option for multipurpose use. The Free Alkaline (FA) values span from 0.06 ±0.01 for Mp_1 to 0.21 ±0.01 for Mp_{10}, with most samples surpassing the ideal FA threshold of 0.1. The pH values range from 7.35 ±0.41 for Mp_8 to 9.58 ±0.05 for Mp_4. While it's important for multipurpose soaps to maintain a balanced alkalinity, samples like Mp_4 and Mp_3 go beyond the optimal pH range of 6.5–8.5. The Moisture content (MC) values vary from 12.55 ±0.06 for Mp_4 to 20.36 ±0.25 for Mp_3, with SON recommending a limit of 5.0. Hardness values range from 8.50 ±0.58 for Mp_4 to 18.50 ±0.58 for Mp_3. Harder soaps, such as Mp_3 and Mp_1, dissolve more slowly, making it ideal for longer-lasting use.

Table 4. *Mean and standard deviation values for multipurpose soap.*

SampleID	TFM%	AI%	FA%	pH	MC%	Hdn(mm)
Mp_1	71.88 ±0.35	0.88 ±0.02	0.06 ±0.01	8.00 ±0.08	16.22 ±0.36	18.00 ±0.82
Mp_2	76.09 ±0.09	13.45 ±0.44	0.15 ±0.01	8.75 ±0.29	16.36 ±0.04	15.25 ±0.50
Mp_3	58.46 ±0.49	16.21 ±0.25	0.19 ±0.04	9.48 ±0.10	20.36 ±0.25	18.50 ±0.58
Mp_4	62.01 ±0.42	11.64 ±0.73	0.15 ±0.01	9.58 ±0.05	12.55 ±0.06	8.50 ±0.58

SampleID	TFM%	AI%	FA%	pH	MC%	Hdn(mm)
Mp_5	73.28±0.15	14.52±0.55	0.07±0.02	7.95±0.06	14.73±0.32	14.00±0.00
Mp_6	75.80±0.01	16.23±0.03	0.18±0.03	8.38±0.25	16.25±0.16	14.75±0.50
Mp_7	65.44±0.26	14.10±0.62	0.11±0.01	8.03±0.05	15.59±0.28	17.00±0.00
Mp_8	63.82±0.39	13.26±0.25	0.12±0.01	7.35±0.41	16.15±0.10	14.50±0.58
Mp_9	64.78±0.01	15.28±0.32	0.15±0.02	8.07±0.05	16.60±0.45	12.50±0.58
Mp_{10}	70.57±0.06	16.29±0.20	0.21±0.01	8.13±0.25	17.43±0.49	15.60±0.00
SON	50-65	15.6	0.1	6.5-8.5	25.0	

Key: Mp_1-Viva+, Mp_2-2Sure, Mp_3-Waw, Mp_4-Fizz, Mp_5-Vlemon+, Mp_6-Fcare, Mp_7-Key, Mp_8-Bright, Mp_9-Kifi, Mp_{10}-Zuma

Table 5 presents the means, standard deviations (SDs), sample sizes (N), and *P*-values for various physicochemical parameters of different soap categories: Toilet, Laundry, Medicated, and Multipurpose soaps. The parameters analysed include Total Fatty Matter (TFM), Alkaline Insoluble (AI), Free Alkali (FA), pH, Moisture Content (MC), and Hardness (Hdn).

Table 5. *ANOVA for physicochemical parameters of soaps.*

Brand	Mean	SD	N	P-value	Physicochemical parameters
Toilet	65.2210	6.33525	40	0.54	
Laundry	65.8308	9.38844	40	0.54	TFM
Medicated	73.0377	2.97356	40	0.54	
M/Purpose	68.2125	5.88155	40	1.00	
Toilet	15.3488	9.55968	40	0.216	
Laundry	13.8520	8.01816	40	0.216	AI
Medicated	9.6055	6.27238	40	1.000	
M/Purpose	13.1843	4.41711	40	0.216	
Toilet	0.0953	0.05139	40	0.325	
Laundry	0.1133	0.05235	40	0.325	FA
Medicated	0.1655	0.13715	40	0.200	
M/Purpose	0.1368	0.04922	40	0.117	
Toilet	8.2900	1.11627	40	0.693	
Laundry	8.3600	0.66979	40	0.693	pH
Medicated	7.3650	0.81005	40	1.000	
M/Purpose	8.3698	0.69742	40	0.693	
Toilet	9.5370	2.77562	40	1.000	
Laundry	16.5745	1.88825	40	0.469	MC
Medicated	5.6883	1.87584	40	1.000	

Brand	Mean	SD	N	P-value	Physicochemical parameters
M/Purpose	16.2257	1.90770	40	0.469	
Toilet	7.0500	1.64784	40	1.000	
Laundry	16.7500	1.79386	40	1.000	Hdn
Medicated	4.3750	1.70501	40	1.000	
M/Purpose	14.8000	2.80293	40	1.000	

The correlation matrix (Table 6) shows the relationships between six physicochemical parameters: Total Fatty Matter (TFM), Alcohol Insoluble (AI), Free Alkali (FA), pH, Moisture Content (MC), and Hardness (Hdn). These relationships are evaluated using Pearson correlation coefficients, with significance levels indicating the strength and reliability of the correlations. TFM shows some interesting dynamics with various parameters. The most notable is its strong negative correlation with AI (-0.619, $p<0.01$), which means that as Total Fatty Matter goes up, the Alcohol Insoluble tends to drop significantly. There are also moderate negative correlations with pH(-0.294, $p<0.01$) and MC(-0.224, $p<0.01$), suggesting that higher TFM values are linked to lower pH and MC levels. On the flip side, TFM doesn't really interact with FA or Hdn, indicating a lack of significant correlation there.

When it comes to AI, it has a weak positive correlation with FA (0.222, $p<0.01$), hinting at a slight tendency for both to rise together. However, AI doesn't show significant correlations with other parameters like pH, MC, or Hdn, which means its behavior is mostly independent of these variables, except for TFM and FA. FA, on its part, has minimal correlations with the other parameters. While it does have a weak positive relationship with AI (0.222), it doesn't significantly correlate with TFM, pH, MC, or Hdn. This suggests that FA operates largely on its own in this context.

The pH parameter, however, reveals more inter connected relationships. It has a moderate positive correlation with MC (0.479, $p<0.01$) and Hdn (0.364, $p<0.01$), indicating that higher pH levels tend to go hand in hand with increases in both MC and Hdn. Interestingly, pH also has a moderate negative correlation with TFM (-0.294, $p<0.01$), meaning that as pH rises, TFM tends to decrease. There are no significant relationships between pH and AI or FA. MC stands out with a strong positive correlation with Hdn (0.947, $p<0.01$), suggesting a nearly perfect relationship between these two. This implies that MC and Hdn are likely influenced by similar underlying factors or processes. MC also shows a moderate positive correlation with pH (0.479, $p<0.01$) and a moderate negative correlation with TFM (-0.224, $p<0.01$). However, it doesn't significantly correlate with AI or FA, emphasizing its unique position in this analysis.

Finally, Hdn shows the strongest positive correlation in the matrix with MC, clocking in at 0.947($p<0.01$), which really high lights the close relationship between these two para meters. On top of that, Hdn has a moderate positive correlation with pH at 0.364($p<0.01$) and a moderate negative correlation with TFM at -0.223($p<0.01$). Interestingly, Hdn doesn't show any significant correlations with AI or FA, suggesting that its behavior is more closely linked to MC, pH, and TFM.

To sum it all up, the key take a ways include the strong negative relationship between TFM and AI, the moderate positive correlations of pH with MC and Hdn, and the exceptionally strong positive correlation between MC and Hdn. These relationships offer valuable insights into how the physicochemical parameters interact within the system being studied.

Table 6. *Correlations Analysis between different Physicochemical Parameters of Soaps.*

		TFM	AI	FA	pH	MC	HD
TFM	Pearson Correlation	--					
	N	160					
AI	Pearson Correlation	-.619**	--				
	Sig.(2-tailed)	.000					
FA	Pearson Correlation	-.006	.222**	--			
	Sig.(2-tailed)	.940	.005				

		TFM	AI	FA	pH	MC	HD
pH	Pearson Correlation	-.294**	.087	.000	--		
	Sig.(2-tailed)	.000	.274	.996			
	N	160	160	160	160		
MC	Pearson Correlation	-.224**	-.001	-.047	.479**	--	
	Sig.(2-tailed)	.004	.990	.553	.000		
Hdn	Pearson Correlation	-.223**	-.006	-.085	.364**	.947**	--
	Sig.(2-tailed)	.005	.940	.286	.000	.000	

**.Correlation is significant at the0.01level(2-tailed).

The dendrogram is a visual tool that illustrates the clustering process out lined in the table, making it easier to grasp the relationships between the physicochemical parameters. On the horizontal axis, you'll find the variables (TFM, AI, FA, pH, MC, and Hdn), while the vertical axis indicates the similarity levels at which these clusters come together. It all starts with each parameter as its own separate cluster. The first to join forces are MC and Hdn, merging at a high similarity level near the top of the dendrogram. This close pairing underscores their strong correlation and their shared roles in molecular stability and decomposition.

Next up, pH enters the MC-Hdn cluster, creating a larger group at a slightly lower similarity level. This combination highlights pH's regulatory influence on hydrolysis and its indirect effect on molecular volume. AI and FA, on the other hand, form their own unique cluster at a moderate similarity level, show casing a solid connection between these parameters as indicators of acidity and alkalinity. Their grouping suggests that they are both influenced by neutralization reactions happening within the system. As the clustering continues, the AI-FA cluster merges with the MC-Hdn-pH cluster at a lower similarity level. This indicates a broader, albeit weaker, relationship between the acidity-alkalinity parameters and those related to hydrolysis.

Finally, TFM joins the overall cluster at the lowest similarity level, which points to its relatively independent behavior compared to the other parameters. This last step highlights that while TFM isn't as tightly linked to the dynamics of the other variables, it still maintains some overall connection to the system. The dendrogram serves as a perfect complement to the amalgamation table, visually demonstrating how the clusters are formed and the varying strengths of the relationships among the parameters. It effectively show cases the hierarchical nature of the clustering process and paints a clear picture of how these physicochemical properties are interconnected.

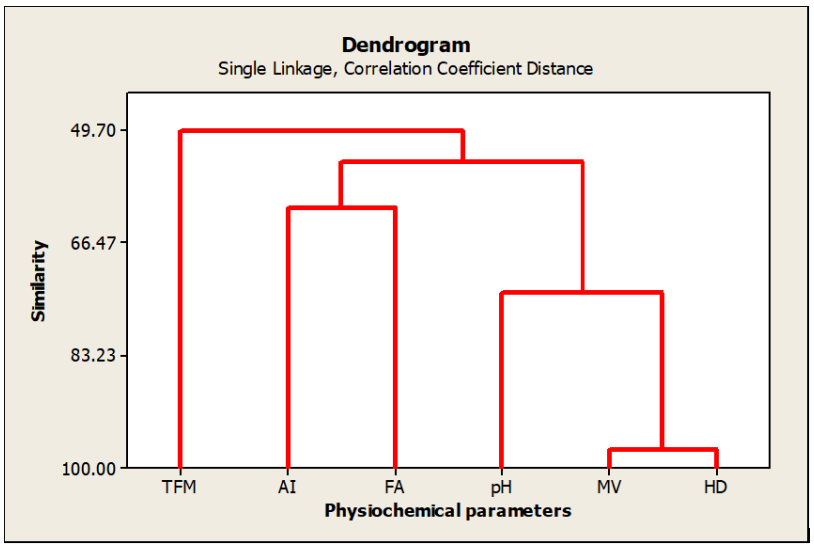


Figure 2. *The Dendrogram Shows the Similarities between various Physicochemical Parameters of Soaps.*

4. Discussion

The data presented in Table 1 indicates that while several samples meet or even surpass SON standards for key quality parameters, there are some significant deviations worth noting. For example, T_2 doesn't quite hit the minimum TFM requirement and has higher AI levels, which could potentially affect both its effectiveness and user safety. On the flipside, samples T_1, T_3, and T_5 shine with their superior quality, boasting higher TFM content and compliance with other important parameters. This analysis really highlights how crucial it is to stick to regulatory standards to ensure the quality of soap and the safety of its users [23]. These results also point out the variability in commercial soap formulations and the pressing need for stricter quality control measures. This aligns with the findings of [18], who reported the physicochemical properties of some soaps, including TFM(55.45), AI(3.5), MC(9.53), and FA(0.09). Additionally, it echoes the report by [20], which indicated the physicochemical parameters of soaps as pH(7.3), MC(10.4), TFM(34), FA(0.56), and AI(20).

Moving on to the analysis in Table 2, it shows that only a handful of samples meet the SON standards across all parameters. L_9 and L_{10} really stand out as high-quality samples, closely aligning with SON specifications for TFM, pH, and FA. However, L_1 and L_3 show some significant discrepancies, including low TFM, high AI, and FA, making them less suitable for safe and effective cleaning. Moreover, most samples exceed the SON limit for MC, which could impact their durability. These findings emphasize the variability in laundry soap formulations and reinforce the necessity for strict adherence to regulatory standards to ensure product quality and consumer safety. The [30] also noted a pH range of (5.5–8.0), moisture(10–16.2), TFM(71-84), AI(20-28), and FA(0.13–0.16).

Table 3 shows that most medicated soap samples meet the SON standards for Total Fatty Matter (TFM) and pH levels, which is great for ensuring effective cleansing and skin compatibility. However, we do see some notable discrepancies in the Alcohol Insoluble (AI) and FreeAlkali (FA) values. For instance, samples M_6, M_9, and M_{10} go beyond the acceptable limits, which could lead to skin irritation. On the brighter side, M_4 stands out with a well-balanced profile, maintaining acceptable values across most parameters. In contrast, M_5 and M_6 exhibit significant deviations in AI, FA, and pH, which could compromise their effectiveness and safety. This aligns with findings from [24], which reported that the physicochemical properties of medical soaps typically range from pH(6.5-7.3), MC(10.4-14.0), TFM(34-65), FA(0.56-0.88), and AI(20-23).

The high moisture content in soap suggests that excess water might react with any unsaponified neutral fat, leading to the formation of free fatty acids and glycerol through a process known as hydrolysis during storage. Moisture content is a key factor in evaluating a product's shelf life [25]. The alkaline nature of soap helps create a barrier against harmful bacteria and viruses by neutralizing the body's natural acidity (which ranges from 5.4 to 5.9), promoting a healthy environment and aiding in lathering. Additionally, soaps with a pH below 5 or above 10 can be harsh on the hands and skin [22]. According to [22], high-quality soaps should have TFM values above 76%, although a minimum of 60% is considered acceptable for safe use of soaps made from selected tallows. The presence of free caustic alkali is another factor that influences the abrasiveness of soap. Based on this study's findings, some FA values fall within the recommended SON limits, while others exceed them. This variation maybe linked to the properties of the oils used in soap production, which affect the saponification rate [18]. The AI value is a crucial parameter for determining soap purity, as noted by [21] high level of impurities in soaps may be attributed to the level of impurities of alkali and oil/fat used for producing the soap.

The analysis presented in Table 4 reveals that a few samples (Mp_1, Mp_5, and Mp_8) show fairly balanced properties, while most others fall short of the ideal standards for AI and FA. Notably, Mp_1 emerges as the most compliant soap, boasting suitable levels of AI, FA, and pH. In contrast, Mp_3 and Mp_{10} displays insignificant discrepancies, with elevated AI and FA values and lower TFM, making them less ideal for sensitive cleaning tasks. The consistently high MC levels across all samples highlight a common issue for multipurpose soaps, which could affect their durability. Although hardness varies quite a bit, Mp_3 stands out with the highest hardness value, enhancing its durability during use. This aligns with findings from [13], which report a pH of 7.5 and hardness of 1.3, respectively.

ANOVA results indicate variations among the physicochemical parameters of different soap brands. Medicated soaps lead with the highest mean TFM at 73.04, followed by multipurpose soaps at 68.21, laundry soaps at 65.83, and toilet soaps at 65.22. The P-value of 0.54 suggests that there are no statistically significant differences in TFM among these groups. This supports previous studies that high light the consistency of TFM levels across soap categories to ensure product effectiveness [26].

When it comes to AI, toilet soaps have the highest mean at 15.35, while medicated soaps come in lower at 9.61. However, the P-value of 0.216 indicates no significant differences among the groups. This finding reflects the industry's approach to formulating soaps to enhance functionality rather than uniformly increasing AI levels [27]. Free Alkaline (FA) levels are highest in medicated soaps at 0.1655 and lowest in toilet soaps at 0.0953. Despite this variability, the P-values (ranging from 0.117 to 0.325) show that FA differences are not statistically significant across soap types. Since excessive FA can irritate the skin, maintaining controlled levels, as observed, is crucial [28].

Medicated soaps have a mean pH of 7.37, which is more neutral compared to other types that hover around 8.3. The P-

value of 0.693 indicates that there are no significant differences among the groups. Keeping the pH close to neutral is really important for compatibility with human skin [29]. When it comes to moisture content(MC), laundry soaps (16.57) and multipurpose soaps (16.23) have higher levels than toilet soaps (9.54) and medicated soaps (5.69). However, the P-values(≥0.469) suggest that these differences aren't statistically significant, meaning there's not much variation in MC that affects soap stability. In terms of hardness, laundry soaps are the toughest at 16.75, while medicated soaps are the softest at 4.38. With P-values all at 1.000, the differences in hardness across the groups aren't statistically significant either. Soap hardness is an important quality factor, but the lack of significant differences here might point to consistent manufacturing practices [30].

5. Conclusion

The analysis of soap samples reveals variability in key quality parameters, including Total Fatty Matter (TFM), Alcohol Insoluble (AI), Free Alkali (FA), pH, Moisture Content (MC), and Hardness (Hdn).

Abbreviations

TFM	Total Fatty Matter
AI	Alcohol Insoluble
FA	Free Alkali
MC	Moisture Content
Hdn	Hardness
pH	pH
SON	Standard Organisation of Nigeria
WHO	World Health Organisation

Author Contributions

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Yusuf Muhammad Bawa: Writing – review & editing
Ibrahim Bako: Writing – original draft
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Mohammed Adamu Garga: Writing – review & editing
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Conflicts of Interest

All authors declared no conflicts of interest.

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