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Use of *Jatropha* Seed Oil and Alkali Solution obtained from Its Ash for Soap Making: An Environmentally Friendly and Cost Effective Approach

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ABSTRACT: The present study investigated the potential of *Jatropha curcas* L. seed oil and lye its ash for soap making. Oil was extracted from the seeds using Soxhlet extractor and n-hexane. Lye solution was obtained by boiling ash of Jatropha with distilled water. The physicochemical properties (saponification value, Iodine value, acid value and peroxide value) of the oil (and its blend with palm oil) were found to be consistent with reported values in literature. The oil content and its relative density were also found to be 31.17% and 0.88g/cm^3, respectively. Soap samples were prepared by treating the oil and the prepared lye solution. Their physicochemical properties (moisture content, total alkali content, total fatty matter, pH, foam ability and cleansing ability) were found to be comparable with reported properties for laundry soaps. The findings indicated that the lye solution from ash of Jatropha and its seed oil result in soap materials that have acceptable qualities.

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Soaps are sodium or potassium salts of fatty acids (triglycerides) that can be prepared by treating fats/oils with sodium hydroxide (NaOH) or potassium hydroxide (KOH) via a process known as saponification reaction. It is known that sodium soaps, prepared from NaOH tend to be harder (Eqn. 1) whilst potassium soaps, prepared from KOH are softer or often liquid (Eqn. 2) (Dixit, 2011; Warra *et al*., 2010; Akbar, *et al*, 2009]. Of the raw material used for soap preparation some of them have competitive utilizations and problems related to quality/stability of soap products. For instance, animal fats/tallows are used for soap making but the competitive utilization of these materials for energy/fuel production created shortage (Thoenes, 2006; Rudy, 2006). Moreover, the soap products made of animal fat could rancid/deteriorate due to improper storage conditions and also it needs scarification of animals (Rafiqa, 2013). Commercial soap production also involves large-scale utilization of vegetable oils (particularly palm oil) and commercial alkali products (Vivian *et al*., 2014; Tincliffe and Webber, 2012; Grain, 2007). However, the competitive uses of palm oil for other purposes such biofuel production made it too expensive to be used by soap factories of developing countries or those countries that are not producers of palm tree (Sonja and Goad, 2006). It can also potentially cause political and economic dependence on palm oil exporting countries as only few Asian countries are dominant in exporting about 80% of palm oil to the world market (Agnes and Jessica, 2015; Alam *et al*., 2015; Bazmi *et al*., 2011). Moreover, the other inputs for soap production are alkali-based reagents such as NaOH and KOH. These chemicals, too, are costly due to their associated very high production costs (https://www.eurochlor.org/wp-content/uploads/2019/04/12-electrolysis-production-costs.pdf). Therefore, looking for alternatives but easily available raw materials is a must for soap production both at commercial and local/small scales

$$\underset{\text{(Fat/Oil)}}{C_3H_5(OOCR)_3} + \underset{\text{(Sodium hydroxide)}}{3NaOH} \longrightarrow \underset{\text{(Soap)}}{3NaOOCR} + \underset{\text{(Glycerol)}}{C_3H_5OH} \quad (1)$$

$$\underset{\text{(Fat/Oil)}}{C_3H_5(OOCR)_3} + \underset{\text{(Potassium hydroxide)}}{3KOH} \longrightarrow \underset{\text{(Soap)}}{3KOOCR} + \underset{\text{(Glycerol)}}{C_3H_5OH} \quad (2)$$

R: refers a long chain hydrocarbon residue

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In search of alternatives for soap production or in order to tackle the aforementioned problems, *Jatropha* plant has been identified as potential source of substitute. *Jatropha curcas* is small tree that produces oil containing seeds (Achene *et al*., 2010). Of several uses of Jatropha, use oil obtained from its seeds in biofuel/biodiesel and soap productions are the most important ones. Jatropha has also been given attention in Ethiopia biofuel production sector as the plant is widely cultivated/distributed and also grown by investors in the country (Tenaw *et al*., 2017; Habitamu, 2014). There are studies showing that soaps can also be made from ashes of agricultural wastes such as cassava peels, palm bunch, cocoa pod, banana leaves, maize cob, sugar beet waste and many others (Onifade, 1884; Onyegbado, *et al*., 2002; Taiwo and Osionowo, 2001; Atiku *et al.,* 2014). When these materials are burnt in air, the resulting ashes that contain oxides of potassium and sodium which when dissolved in water yield the corresponding hydroxides. *Jatropha* plan has no food competition in animals and human beings, and thus, can be considered as good candidate to produce alkali solution from its ash and oil from its seed for soap production. If attention is given by concerned stake holders to preparation of alkali solution from this plant, that grows abundantly, it can save a lot of hard currency that is needed for importing alkali-based chemicals for soap production. It can also help as job creating opportunity for those citizens participating in preparation of such solution from the ash of Jatropha plant. Though there are plenty of literature reports on the use of *Jatropha* seed oil for soap production there is no information on production of soap from ash (of alkali) of *Jatropha curcas* that is available in abundance everywhere in Ethiopia. The objective of this study is, therefore, to assess potential of this plant as source of alkali solution for preparation of soap. Thus, alkali solution was prepared from ash of the whole plant part, and was used to prepare soap by treating it with seed oil of the same plant.

MATERIALS AND METHODS

Chemicals/Reagents: The materials and chemicals used in this study were n-hexane, sodium chloride, hydrochloric acid, potassium hydroxide, potassium iodide, starch, chloroform, sodium thiosulphate, ethanol, glacial acetic acid, nitric acid, sulphuric acid, EDTA and phenolphthalein. All the chemicals other than the oil samples were of analytical grade and used without further purification.

Collection of plant materials: Jatropha seeds and plant materials (shell, stem, and leaves) were collected from Haro Dumal, Berbere woreda of Bale zone, Southern Ethiopia (Figure 1). Palm oil and three randomly selected commercial laundry soaps (Robi, Yaf and Zumra) were purchased from local supermarkets in Hawassa city, Ethiopia.

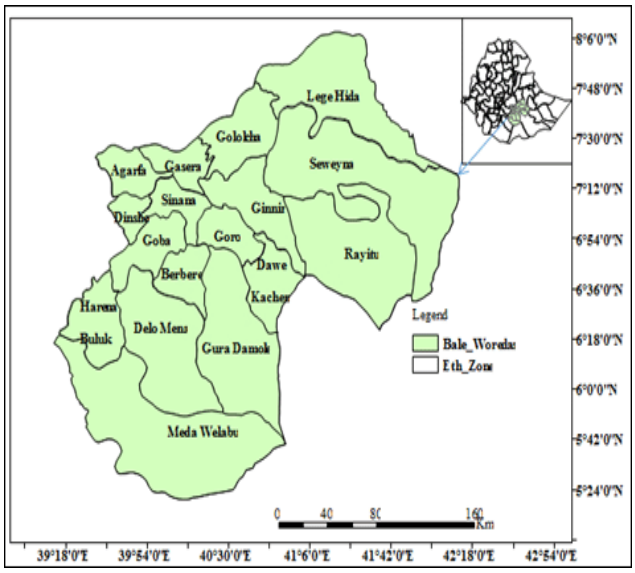

Fig 1. Administrative map of Bale zone (Bekele *et al*., 2017).

*Oil extraction***:** Four kilograms of *Jatropha curcas* seeds were collected for the experiment. The damaged seeds were discarded and only healthy and clean seeds were selected for oil extraction. The selected seeds were dried in a shade for some time before use. The dried seeds were deshelled. The deshelled seeds were then crushed into fine powders with the aid of mortar and pestle. The powder (20 g) was then subjected to Soxhlet extraction using an organic solvent (200 ml n-hexane) for six hours (Warra *et al*., 2012; Amalia et al., 2013). The extraction was repeated five more times following the same procedures. The solvent was

removed under reduced temperature and pressure using rotary evaporator. The oil was then recovered from the mixture by drying the residual extracting solvent in an oven at 60 ^{0}C for one hour and stored in a bottle in freezer until used for subsequent physicochemical analyses.

Preparation of ash: Four kilograms of the plant material (stem, shells and leaves of Jatropha) were burned in an open air-rich locally constructed stove. The stove helped to trap and prevented the ash from being blown off by air current. The unburned black components (charcoal) were separated from the finest white ashes with flour sifter. The unburned plant material (charcoal) was heated on a furnace at a temperature of about 600 ^{O}C until the entire sample in the crucible completely turned to ash. Finally, the ash was allowed to cool (Warra, 2010).

Extraction of alkali from ashes: Forty grams of whit as was mixed with 400 ml of distilled water in a 800-ml beaker. The mixture was then heated for 30 minutes. The mixture was then cooled and filtered. The resulting alkali solution was heated over water bath for 90 minutes to reduce the volume that ultimately ensures formation of alkali solution of the required strength. The formation of alkali solution of such alkalinity strength was tested by placing fresh eggs. The floating of the egg was used as indicator for formation of alkali solution of the required strength. The pH of the solution was also measured using calibrated pH meter.

Physicochemical analysis of seed oil: The physicochemical analysis of *Jatropha* oil was carried out using standard methods reported in literature (Hautfennem, 1992; Atiku *et al.,* 2014). The physicochemical properties investigated were acid value, iodine value, saponification value and peroxide value.

Determination of relative density: Approximation method was used to determine the density of the oil as follows. 5 ml of oil sample was measured and transferred into a cylinder of known weight. The weight of the cylinder including its contents was measured and its relative density was calculated as described in literature (Elizabeth *et al*., 2012). The measurement was made in triplicate, and average value was recorded as relative density of the extracted oil.

$$\text{Relative Density} = \frac{\text{Weigh of sample (g)}}{\text{Volume of sample (mL)}}$$

*Determination of percent yield of oil***:** 20 gram of the powdered dry *Jatropha* seeds was subjected to Soxhlet extraction for 8 hours using n-hexane (as a solvent) for 8 hours. The solvent was removed under reduced temperature and pressure by evaporating it using rotary evaporator followed by refluxing the lipid extract in a boiling water bath. The oil obtained was then weighed using analytical mass balance. The same procedures were repeated in triplicates and the percent yield of the Jatropha seed oil was calculated from the averages masses of oil divided by mass of seeds (20 g).

Acid value: Two and half grams of pure *Jatropha* oil were put into a 20 ml of ethanol containing 250-mL conical flask. The flask was heated on a steam bath for 3 minutes. Then the flask was cooled and the contents titrated with 0.1N alcoholic potassium hydroxide solution using phenolphthalein as an indicator. Also, a blank titration was conducted side by side and the acid value was calculated as described in literature (ISO660, 1996). The experiment was carried out three times, and average value was recorded as volume (in ml) of KOH solution used in this experiment. Similar procedures were repeated for palm oil and oil blends (Jatopha oil and palm oil).

$$\text{Acid Value} = \frac{56.1 \text{ x V x N}}{\text{W}}$$

Where; V=Volume in ml of standard KOH used; N=Normality of KOH used, W=Weight of the oil sample in grams

Saponification value: Saponification value was determined using method (AOAC, 2000). Two gram of oil was weighed accurately by transfer method into a 250-mL round bottom flask. Freshly prepared 0.5N alcoholic potassium hydroxide solution (25 mL) was added into the oil sample by means of pipette and the mixture was gently refluxed on a water bath (at 55 ºC) using an air-condenser for one hour with continuous stirring. The solution was heated further for 1 hour. Then the flask was cooled, the condenser tip was washed with little distilled water and the excess KOH was titrated against 0.5N hydrochloric acid solution using phenolphthalein as indicator. The experiment was done in triplicate and average value was taken for data analyses. Similar procedures were employed for palm oil and oil blend used in the experiment. A blank titration was also carried out simultaneously**.**

$$\text{Saponification Value} = \frac{28.06 \text{ x V}}{\text{W}}$$

Where; V=Average volume of KOH in ml; W=Weight of the oil sample

Peroxide value: Exactly 2.0 g of the oil sample was transferred into a 250-ml flask and one gram of powdered potassium iodide (KI) followed by addition of a solvent mixture (2:1) of glacial acetic acid and trichloromethane. The solution was placed on a water bath for a few minutes for complete dissolution. 20 ml of 50% KI was introduced into the mixture and it was titrated with 0.1M $Na_2S_2O_3$. The indicator was a regular starch solution. The measurements were made in triplicate, and average values were taken for data interpretation. The same procedures were employed for palm oil and oil blend used in the experiment. Blank titration was also carried out simultaneously.

$$\text{Peroxide Value} = \frac{B \times S \times M}{W}$$

Where S and B stands for the sample and blank in terms of titre value, respectively. W = weight of the sample; M = molarity of $Na_2S_2O_3$

Preparation of soap:

(i) Preparation of soap from pure Jatropha oil without additives. 20g of *Jatropha* oil was poured into a 500-ml beaker and heated to a temperature at about 60-70 ^{O}C. A mixture of purified alkali (obtained from ash) and ethanol (50:50% by volume) was added continuously into the beaker containing the oil with continuous stirring until the mixture becomes thickened. 20 ml of NaCl solution was added for salting out water, glycerin and other impurities, and the soap was completely homogenized for 30 minutes. Two layers were formed in the beaker with the soap formed a layer on the surface of the beaker while lye (a solution of glycerol and borne) was low. The lye was separated by means of separatory funnel. Finally, the soap was poured into a mould for cooling applying same procedures as was indicated in literature (Warra, 2009).

(ii) Preparation of soap from *Jatropha* oil (in the presence of additive)

The procedure from section 3.3(i) was conducted followed by addition of small amount of EDTA molecule. The EDTA molecule was added in order to maximize the binding ability of water molecules so that the performance of the prepared soap would also be maximized.

(iii) Preparation of soap by oil blend (palm oil + Jatropha oil (1:1w/w)) without additives

The procedure from section 3.3(i) above was followed using a mixture of 10 g of Jatropha oil with 10g of Palm oil.

(iv). Preparation of soap by blending palm oil and Jatropha oil (1:1 w/w) with additives

The procedure from section 3.3(i) was followed using 10g of *Jatropha* oil, 10g of palm oil, about 60 ml of alkali solution, 60 ml of ethanol, 20 ml 10%NaCl solution and small amount of EDTA molecule as an additive.

Physicochemical properties of the soaps: The properties of the prepared four different types of soaps and three commercially manufactured soaps (Robi, Yaf and Zumra) were determined as described in the following sections.

*Moisture content***:** A sample of the 5g scrapped soap sample was put into a petri dish and placed in an oven for 1 hour at 105°C. This was repeated until a constant weight was reached. It was allowed to cool down and then weighed. The moisture content in percentage was determined from loss in masses (ISO 672, 1978; AOCS, 1997) using the formula;

$$\text{Moisture Content} = \frac{W_i - W_f}{W_i} \times 100\%$$

Where W_i = weight of the sample before drying; W_f = weight of the sample after drying

Total alkali content: The total alkali content was determined by titrating excess acid contained in aqueous phase with standard volumetric NaOH solution according to method (AOCS, 1997). 5 g of each soap sample was added into 100 ml of neutral ethanol and then 5 ml of 1N H_2SO_4 solution added. The mixture was heated until the soap sample got dissolved. The test solution was titrated against 1N NaOH using phenolphthalein as indicator. The measurement was done in triplicate, and average values recorded. The total alkali content was calculated using the following formula (Betsy *et al*., 2013).

$$\text{Total Alkali Content} = \frac{V_a - V_b}{W} \times 3.1$$

Where W = weight of the soap sample; Va = volume of acid; Vb= volume of base

Total Fatty Matter: Determination of total fatty matter followed a method described in literature (AOCS, 1997; Betsy *et al*., 2013) with slight modifications. 5 gram of soap sample was dissolved in 100 ml hot water that was added to it in a 250-ml beaker. About 40 ml of 0.5N HNO_3 or H_2SO_4 was added to make it acidic. The mixture was heated on the water bath until fatty acids were floating as a layer above the solution. It was cooled in ice water to solidify the fatty acids. The fatty acids were separated and the aqueous solution was treated with 50 ml chloroform to remove the remaining fatty acids using separatory funnel. The separated fatty matter was mixed together, solvent was evaporated and the yield was weighed in a previously weighed dish. From the difference in weight, the % of fatty matter was calculated using method.

$$\text{Total Fatty Matter} = \frac{Y - X}{W} \times 100\%$$

Where X = weight of the porcelain dish (g); Y = weight of soap after drying + X; W = Weight of soap sample before drying (g)

pH determination: The pH of the prepared laundry soaps and those of the three commercial soap samples was determined using a pH meter (Model; PHS-3C DC-6V 300mA). 10 g of the soap shavings were weighed and dissolved in distilled water in a 100-ml volumetric flask. This was done to prepare 10% soap solution in line with literature report (Umar, 2002). The electrode of the pH meter was inserted into the solution and the pH value was recorded. The experiment was done in triplicates. Similar procedures were employed on three commercial soap samples (for the sake of comparison) and oil blends.

Solubility test: Exactly 2 gram of each soap sample was weighed and ground to powder form and subsequently allowed to dissolve in 100 ml of distilled water with vigorous stirring for 2 minutes. The extent of the formation of uniform soap solution was noted. Similar procedures were repeated for the commercial soap samples for comparison (Umar, 2002).

Foam ability test: The method reported (Isah, 2006) for synthetic detergent was adopted. About 2.0g of the soap shavings were added to a 500-ml measuring cylinder containing 100 ml of distilled water. The mixture was shaken vigorously so as to generate foams. After shaking for about 2 minutes, the cylinder was allowed to stand for about 10 minutes. The height of the foam in the solution was measured by method (Neu, 1960) and recorded. The experiment was done in triplicates. Similar procedures were employed on three commercial soap samples (for the sake of comparison).

Test for effectiveness in cleaning: To determine the cleaning property of the prepared soaps, a drop of mineral oil was placed on four separate strips of filter papers. The filter papers with the oil spots were immersed into separate test tubes containing soap solutions (2 g soap shavings/100 ml distilled water each) and shaken vigorously for 1 minute.

The filter papers were removed and rinsed with distilled water and the degree of cleanliness in each filter paper was observed (Warra *et al.,* 2010). The experiment was done in triplicates. Similar procedures were employed on three randomly selected commercial soap samples (for the sake of comparison).

RESULTS AND DISCUSSION

*Extraction of alkali and determination of its alkalinity strength***:** Some studies indicated that an alkali solution extracted from wood ash has equivalent performance to commercial bases such as NaOH and KOH particularly in soap making (Onyegbado *et al.,* 2002). Furthermore, it has been reported that the use of natural vegetable matter such as oil and alkali solution for soap making is cost effective as compared to the costs of commercial chemicals such as NaOH and KOH (Etiegni and Campbell, 1991). The performance of a particular alkali solution generally depends on its concentration. The more highly concentrated the alkali is the higher will be its performance in soap making. The pH value of the alkali solution extracted in this study was found to be 12.63 which is an indication of its high alkalinity strength. This strength was achieved by heating the solution strongly on a water bath until half of the water has been evaporated. The achievement of the desired strength of the alkali solution was confirmed by the floatation of fresh egg just above half-way of the entire alkali solution (Figure 2). The performance of this alkali solution was found to be as effective as the performance of ashes from agricultural wastes described in literature which are useful for traditional black soap production (Taiwo and Osionowo, 2001). It was based on such information, the concentrated alkali solution that was extracted from the ash of whole parts of *Jatropha curcas* plant was used for soap making in the present study.

Fig 2 A less concentrated alkali solution with a fresh egg at the bottom of the solution (a) and a highly concentrated alkali solution with an egg floating half-way above the alkali solution (b).

Oil extraction and determination of oil content: The extraction of *Jatropha* seed oil using Soxhlet extraction is standard method reported in literature (Warra *et al*., 2012; Amalia *et al.,* 2013). n-hexane was chosen as the best solvent for the Soxhlet extraction of *Jatropha* seed oil due to its relative low boiling temperature (40-60 ^{0}C) as compared to most organic solvents and also due to its easy disposability after use (Suzana *et al*., 2003). Determination of oil content in

seeds is very important because it helps to predict the potential of a particular seed as source of oil. High oil content in seeds implies that processing it for oil production would be economically viable. The oil yield of the *Jatropha curcas* seeds obtained in the present study was found to be 31.17%. This value is lower than oil yield (42.19%) reported from Tigray region, Northern Ethiopia (Teklit and Afework, 2015). Such variation in oil content across species and locations might be attributed to differences in species variety, ripening stage, soil fertility, and extraction method, harvesting time, nature of solvent and environmental conditions of varied regions (Yadessa *et al*., 2020; Pant *et al*., 2006). Nevertheless, the oil yield (31.17%) obtained in the present study is a sufficient condition to characterize the seeds as oil seeds. According to FAO, seeds that contain oil yield greater than 17% are considered as oil seeds (CODEX Alimentarius Commission, 1969). With this relative high percentage oil yield (31.17%), the processing of the *Jatropha* seed oil for soap making purpose would be of greatest economic importance both locally as well as industrially. As it has been observed from Figure 3 below, the extracted oil was found to be a yellow liquid with a characteristic fruity odor at room temperature. The observed color is consistent with the color reported in literature (Grainge, and Ahmed, 1989).

Figure 3. The oil extracted from *Jatropha curcas* seeds using soxhlet extractor

Physicochemical analysis of the oil samples: The physicochemical analysis of the extracted *Jatropha* seed oil, palm oil and their blends (50:50% by weight) with/without additives were carried out following the standard methods (Hautfennem, 1992; Atiku *et al.,* 2014) in order to justify their quality and suitability for soap production.

Determination of relative density of the oil samples: The relative density of the *Jatropha curcas* seed oil extracted in the present study was found to be 0.88 g/cm^3. This value is lower than the relative density *Jatropha* seed oil (0.93g/cm^3) reported in literature (Warra *et al*., 2012). These variations could be attributed to some factors such as species variety, ripening stage of seeds, storage conditions, soil fertility and other environmental and geological differences (Teklit and Afework, 2014). The observed lower relative density of *Jatropha* seed oil as compared to the density of water (1 g/cm^3) is also a good advantage that qualifies the oil for soap production due to high tendency of the oil soap to easily emulsify and transport through aqueous solution.

Determination of acid value: Acid value indicates the proportion of free fatty acids present in an oil or fat products. It may be defined as the number of milligrams of caustic potash required to neutralize the acid in 1 g of the sample. The acid values determined in the present study for pure Jatropha seed oil, palm oil, and for the blend of Jatropha and palm oils (50:50% by weight) were found to be 3.96±0.11 mgKOH/g, 16.02±0.12 mg KOH/g and 10.37±0.54 mg KOH/g, respectively (Table 1). Reports revealed that high acid value indicates a stale oil or fat stored under improper conditions. On the other hand, low acid value of an oil product indicates that the oil will be stable over a long period of time and stable against rancidity so that it will be suitability for soap making (Aremu *et al*., 2015).

Thus, the acid value obtained for pure Jatropha seed oil (3.96 ±0.11 mgKOH/g) was much lower than that of palm oil and its blend with Jatropha seed oil (50:50% by weight) which indicates maximum purity and suitability of the extracted Jatropha seed oil for soap production. Furthermore, the acid value of Jatropha seed oil (3.96±0.11mg/KOH/g) is relatively comparable with the acid value of ground nut (4 mgKOH/g) recommended by a Codex Alimentarius commission for using this oil for soap making (FAO, 2015).

Therefore, the oil extracted form Jatropha seed, in the present study, can be used as raw material for soap production. Similarly, the acid value of the blend of Jatropha seed oil and palm oil (10.37±0.54 mgKOH/g) and that of palm oil (16.02±0.12 mgKOH/g) are lower than that of olive oil (17.0 mgKOH/g) (Benge, 2006) which signifies their suitability for soap production, but under minimum purity to get soap products of better quality.

Table 1. Chemical parameters of the analyzed oil samples.

S/No.	Soap sample	Acid Value (mg KOH/g)	Saponification value (mg KOH/g)	Peroxide value
1	Jatropha seed oil	3.96±0.11	163.27±0.00	0.02±0.01
2	Palm oil	16.02±0.12	188.38±1.51	1.215±0.24
3	Blend of *Jatropha* seed oil and palm oil	10.37±0.54	208.02±1.14	0.90±0.25

Saponification value: The number of milligrams of KOH or NaOH needed to saponify 1 gram of oil or fat is known as Saponification value. Saponification value gives information concerning the characteristics of the fatty acids of the fat or oil. The longer the carbon chain, the less acid is liberated per gram of fat hydrolyzed. It is also considered as a measure of the average molecular weight (or chain length) of all the fatty acids present (Hautfennem, 1992; Atiku *et al.,* 2014). Long chain fatty acids found in fats or oils have low saponification value because they have a relatively fewer number of carboxylic functional groups per unit mass of the fat or oil, and therefore, high molecular weight. It has been reported that oils with high saponification value such as coconut oil (257.0mgKOH/g) and palm oil (199.1mgKOH/g) are better used in soap making (FAO, 2015). The saponification values obtained in the current work for Jatropha seed oil, palm oil and for the blend of Jatropha seed oil with palm oil (50:50% by weight) were 163.27±0.00 mgKOH/g, 188.38±1.51 mgKOH/g and 208.02±1.41 mgKOH/g, respectively (Table 1). Since the saponification value of the oil blend was higher than those of the individual oils, it can be possible to make a generalization that the blended oil can be considered as best (as compared to the other two) raw material for soap making. The obtained saponification values were lower than in coconut oil (253.2mgKOH/g) (Abayeh *et al.,* 1998) but higher than the oil obtained from cassia siamea (56.10 mgKOH/g) and beeswax (93 mgKOH/g) (Oshinowo, 1987) which are commonly used for soap making. This indicates that Jatropha seed oil, palm oil and a blend of Jatropha seed oil and palm oil can be used for soap production since their saponification values fall within the acceptable ranges (See the above literature data).

Peroxide value: The peroxide values (pv) for Jatropha seed oil, palm oil and the blend soap of Jatropha and palm oils (50:50% by weight) obtained in the current study were 0.02±0.01meq O_2/Kg, 0.90±0.25meq O_2/Kg and 1.215±0.24meq O_2/Kg, respectively (Table 1). According to Epka and Epke (Mabrouk, 2005), high pv is associated with high rancidity rate. Thus, the low pvs obtained for the three oil samples indicated that the oils were less liable to rancidity, and therefore, could be used for soap production.

Physicochemical analysis of soap samples: The physicochemical properties of soaps determine their quality as well as their efficiency and their cleansing properties. Thus, the physicochemical properties such as moisture content, FAC, TFM, solubility, pH, foam and cleansing ability of the prepared soaps were analyzed relative to the three commercial soap samples following standard protocols such as EAS (EAS, 2013) and ISO (ISO 685, 1975) specifications**.**

Determination of moisture content: Moisture content (MC) is a parameter that is used in assessing the shelf-life of a product (Hautfennem, 1992). The MCs of Jatropha seed oil with and without additives, and that of blend soap of Jatropha and palm oils with and without additives were found to be 10%, 10.5%, 10%, 16%, 18.5%, 11%, 16% and 15%, respectively (Table 2). All the results were comparable with each other and also are in the range of the recommended percentage (10-15%) (Mabrouk, 2005). The implication of high MC in soap is that the excess water could possibly react with any unsaponified neutral fat or oil to give free fatty acid and glycerol in a process called hydrolysis of soap on storage (Encyclopedia of Industrial Chemical Quality Assessment of Soaps analysis, 2007). While high MC in soaps contributes to less foaming and hardness of soaps, low MC is indicative of good foaming and cleansing properties of soaps.

Table 2. The moisture contents of the soap samples.

S/No	Soap sample	Moisture content (%)
1	Jatropha oil soap without additive	10
2	Jatropha oil soap with additive	10.5
3	Blend soap of Jatropha seed oil and palm oil (50:50% by weight) without additive	10
4	Blend soap of Jatropha seed oil and palm oil (50:50% by weight) with additive	16
5	Palm oil soap	18.5
6	Robi (commercial soap)	11
7	Yaf (commercial soap)	16
8	Zumra (commercial soap)	15

Since the MCs determined for all the analyzed soap samples, in the present study, were within the range of the EAS (EAS, 2013) and ISO standard (less than 30%), production of laundry soap from Jatropha seeds oil would result in high quality product (ISO 685, 1975).

Total alkali content: The total alkali content (TAC) is the sum of free caustic alkali and the free carbonated alkali contents expressed as a percentage by mass either as NaOH for sodium soaps or KOH for potassium soaps Hautfennem, 1992; Atiku *et al.,* 2014). The TACs of the soaps prepared from Jatropha seed oil and its blend with palm oil are found to be comparable with the soaps prepared from palm oil and other three commercial laundry soaps (Robi, Yaf and Zumra) purchased from local markets (Table 3). All the results indicated that the soaps prepared from Jatropha seed oil and its blend were found to be comparable with the EAS specification for grade I and grade II laundry soaps (0.2-0.3) as described in literature (EAS; 2013; Tewari, 2004) but lower than the specification set by Bureau of Indian Standard (BIS) which specifies that soaps must have TAC of less than 5% (Bureau of Indian Standards, 2011). The values are also lower than the maximum TAC value of 2% specified by ISO (ISO 685, 1975). Thus, the obtained lower alkali contents indicated that the prepared soap materials to have acceptable quality.

Table 3. Total alkali contents and total fatty matter values of the soap samples

S/No	Soap samples	TAC (meq/g)	TFM (%)
1	Jatropha oil soap without additive	0.35±0.35	56
2	Jatropha oil soap with additive	0.33±1.12	58
3	Blend soap of Jatropha oil and palm oil (50:50% by weight) without additive	0.41±0.81	58
4	Blend soap of Jatropha oil and palm oil (50:50% by weight) with additive	0.31±0.47	66
5	Palm oil soap	0.43±1.02	64
6	Robi (commercial soap)	0.37±0.01	62
7	Yaf (commercial soap)	0.47±0.02	54
8	Zumra (commercial soap)	0.27±1.32	62

Total Fatty Matter: Total fatty matter (TFM) refers to any water-insoluble fatty material obtained by decomposing the soap with a mineral acid under the conditions specified (Hautfennem, 1992; Atiku *et al.,* 2014). It is also defined as total amount of fatty matter that can be separated from a sample after splitting with mineral acid, usually HCl. TFM is one of the most important characteristics describing the quality of soaps and it is always specified in commercial transactions. Soaps are graded in terms TFM. Lower TFM is usually associated with hardness and lower quality of soaps. The TFM measures the quality of soap, and the accepted percentage value for toilet soap is between 76-77% while that of laundry soap is between 50%-76% (Bureau of Indian Standards, 2011; EAS, 2013). The best blend is also selected mostly on the basis of TFM.

For oil blend of Jatropha seed oil and palm oil (50:50% by weight) with EDTA molecule as an additive, TFM was the highest at 66% which falls in the range of TFM required for grade I soap. The remaining three prepared soaps namely Jatropha seed oil soap with additive (58%), palm oil soap (64%) and blend soap of Jatropha and palm oils without additive (58%) have shown comparative TFM values with the commercial soap samples namely Robi and Zumra (with TFM value of 62% each) (Table 3) all of which could fit the grade II standard. The lowest TFM were of Yaf (commercial soap) with 54% followed by Jatropha oil soap without additive (56%) which makes both soaps fit for laundry soaps in accordance with EAS and ISO specification which specifies 76% for grade I, 62% for grade II and 50 for grade III soaps (Bureau of Indian standards, 2011; EAS, 2013).

pH determination: The ability of a cleaning chemical agent to neutralize fatty substances depends on the alkalinity of a particular soap product. Soap with highest pH value has the greatest cleansing ability but has the greatest damage to cotton fabrics. In the present study, the pH values of Jatropha oil soap products without additive, Jatropha oil soap with additive, a blend of Jatropha oil and palm oil without additive as well as with additive, palm oil soap, and those of three commercial soaps (Robi, Yaf and Zumra) were found to be 9.66,9.66. 10.59. 10.62, 10.80, 10.77, 10.60 and 10.65, respectively (Table 4). The pH values of all the analyzed soaps were found to be comparable with each other and found to be of the same category (pH 9-11), all of which are considered as high level pH values by National Agency for Food and Drug Administration and control (NAFDAC)(Umar, 2002).

This might be resulted from incomplete alkali hydrolysis resulting from the saponification process which can be overcome by the addition of excess oil

or any other super fatting agent to reduce the harshness of the soaps (ISO 685, 1975). Thus, the pH values of the prepared soaps materials can be modified to standard levels (pH 6-9) [(Tarun *et al.,* 2014) either by resting them for about 4-6 weeks or adding super fatting agent so that they can be as friendly as possible to our skin and fabric.

Table 4. The pH values of the soap samples analyzed in the present study

S/No	Soap sample	pH value
1	Jatropha soap without additive	9.66±0.07
2	Jatropha soap with additive	9.66±0.00
3	Blend soap of Jatropha seed oil and palm oil (50:50% by weight) without additive	10.59±0.01
4	Blend soap of Jatropha seed oil and palm oil (50:50% by weight) with additive	10.62±0.00
5	Palm oil soap	10.80±0.01
6	Robi (commercial soap)	10.77±0.01
7	Yaf (commercial soap)	10.60±0.01
8	Zumra (commercial soap)	10.65±0.00

Foam ability of analyzed soaps: Lathering power or foam ability refers to the amount of foam that soap forms and it is related to the cleaning ability of soap. Foam helps to suspend dirt by creating greater surface tension in water and trapping dirt for easy removal through rinsing. Foam is generated by agitating surfactant solutions, cushions fabrics against the beating and rubbing that occurs during domestic laundering, thereby reducing fabric damage. Although foam generation has little to do with cleansing ability (Atiku *et al*., 2014; Hart and DeGeorge, 1980), it is of interesting importance to the consumer and is, therefore, considered as a parameter in evaluating soaps and detergents.

Table 5. Comparison among the foam heights of soaps

S/No	Soap sample	Foam height (cm)
1	Jatropha soap without additive	4.88±0.35
2	Jatropha soap with additive	5.83±1.12
3	Blend soap of Jatropha seed oil and palm oil (50:50% by weight) without additive	4.26±0.81
4	Blend soap of Jatropha seed oil and palm oil (50:50% by weight) with additive	5.71±0.01
5	Palm oil soap	3.94±1.98
6	Robi (commercial soap)	5.45±0.02
7	Yaf (commercial soap)	4.63±0.87
8	Zumra (commercial soap)	5.57±0.63

The foam height (in cm) determined in this study for Jatropha oil soap without additive and with additive, blend soap of Jatropha seed oil and palm oil (50:50% by weight) without additive and with additive, Palm oil soap, Robi, Yaf and Zumra soap were found to be 4.8, 5.8, 4.2, 5.7, 3.9, 5.4, 4.6 and 5.5, respectively (Table 5). Of all the eight soap solutions analyzed, foam height of Jatropha oil soap with additive (5.8 cm) and that of blend soap of Jatropha seed oil with palm oil (5.7 cm) were found to be the highest while foam height of palm oil soap (3.9 cm) to be the smallest.

Solubility and cleansing ability of soaps: The solubility of any soap gives an indication on the ease with which the soap will dissolve in water under washing conditions. The amount of cloudy film formed gives an indication on the number of micelles (soap molecules) formed by the soap in water (Mabrouk, 2005). The cloudier the soapy water becomes the more micelles are formed. The number of micelles formed can be attributed to the cleaning action of a particular soap. Thus, Jatropha oil soap with and without additives, blend soap with additive among the prepared soaps in the current work, and Robi and Zumra among the analyzed commercial soaps were found to be appreciably soluble in distilled water while a blend soap without additive, palm oil soap and Yaf were either moderately or slightly soluble (Table 6).

Table 6. The solubility and cleansing abilities of the prepared soap products and commercial soaps used in the study

S/No	Soap samples prepared from	Solubility in water	Cleansing ability
1	Jatropha soap without additive	Highly soluble	High
2	Jatropha soap with additive	Highly soluble	High
3	Blend soap of Jatropha seed oil and palm oil (50:50% by weight) without additive	Highly soluble	High
4	Blend soap of Jatropha seed oil and palm oil (50:50% by weight) with additive	Highly soluble	High
5	Palm oil soap	Moderately soluble	Good
6	Robi (commercial soap)	Highly soluble	High
7	Yaf (commercial soap)	Moderately soluble	Good
8	Zumra (commercial soap)	Highly soluble	High

The chemistry behind the observed differences among the solubility of the analyzed soap samples could be attributed to the positive effect of the EDTA molecules that was added to the soaps during saponification processes. This is because their addition to soap products helps to bind with any free calcium or magnesium ions to prevent soap scum (a process called sequestration) (Smulders, 2002). The cleansing ability of soap is due to the chemical structure of soap molecules, where one end is lipophilic and the other is hydrophilic.

This dual polarity enables the soap to exhibit its cleaning ability (Ekop *et al.,* 2007). Among the analyzed eight soap samples, it was observed that the oil stains were best washed off by Jatropha oil soap without additive, Jatropha oil soap with additive, blend soap with additive, Robi (commercial soap) and Zumra (commercial soap) as compared to the cleansing ability of the other three soap samples analyzed simultaneously (Table 7). This indicated the high cleansing ability of Jatropha seed oil soap as well as its blend with palm oil (50:50% by weight). Therefore, the observed high cleansing ability of Jatropha oil soap both in pure and blend form is an indication of high quality of Jatropha seed oil and lye of Jatropha ash for soap production. All these observations suggest that Jatropha can be used to prepare cost effective laundry soaps by any one (even non-educated individuals) can prepare soap from jatropha getting the necessary rw materials from this plant (i.e., all inputs from one source).

Conclusion: The physicochemical properties of the prepared lye solution obtained from ash and oil extracted from seed of Jatropha tree and the prepared soaps from these materials suggested the possibility of preparation of good quality soaps. Moreover, the results suggested the possibility of reducing dependency on countries that export palm oil and commercial alkalis as it is possible to prepare oil from Jatropha seed and lye solution from its ash in cost effective and greener approaches in areas where this tree is growing in abundance.

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