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(RESEARCH ARTICLE)

The potential of water hyacinth ash as source of alkali soap for soap making: An alternative option to control environmental pollution

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Abstract

This study was carried out to investigate the potential of water hyacinth as a source of alkali solution for soap making and also its utilization as a possible option for its control. The ash of water hyacinth was boiled with distilled water to prepare the alkali solution. Alkalinity (pH) the resulting solution was tested using chemical indicators and pH meter to assess its suitability for soap making, and it was found to be 10.85. The prepared alkali solution was heated with used cooking oils to prepare soap by a process known as saponification. The moisture content, total free alkali content, total fatty matter and the pH values of the prepared soap materials were found to be in the ranges of 24.3-37.8%, 0.46-0.77, 68.2-72.8 and 9.82-10.33%, respectively. These values are in acceptable ranges for good grade laundry soaps. The data also suggested that water hyacinth ash can be used as source of alkali solution for soap making. It is, therefore, possible to control environmental pollution caused by water hyacinth using its ash in soap making.

Keywords: Total Fatty Matter; Moisture Content; *Eichhornia crassipes*; Oil; Saponification; Lye Solution

1. Introduction

Water hyacinth (*Eichhornia crassipes)* is a harmful weed that grows widely on water bodies and muddy lands (Anujasharma *et al*., 2016; Ebro *et al*., 2017). Reports revealed that the weed has been originated from Amazon Basin, and rapidly spread to Tropical, Sub-tropical and Pacific regions of the world (Julien *et al.* 1999; Julien *et. al*., 2001; Hossain, 2008; Jayanthi *et al*., 2011).

Water hyacinth causes environmental pollution by covering the surfaces of water bodies. This, in turn, has serious consequences such as affecting irrigation, power generation, fishing, water transportation, and reduction of biodiversity. Experiences showed that it also reduces crop productivity and animal breeding as it invades farm lands and grass lands, respectively (Misfwa *et al.*, 2001; Brendonck, 2003; Malik, 2007). Its leaves are known to cause high rate of evapotranspiration resulting in water scarcity in areas where it grows abundantly. Its infestation of water bodies result in a wide spread of malaria and bilharzia as it creates favorable conditions for breeding mosquitoes and other insects that are acting as vectors (Cock *et al*., 2000; Gunnarsson and Petersen, 2007; Anujasharma *et al*., 2016).

Currently, three methods namely chemical, physical and biological methods are being used commonly to control water hyacinth in order to overcome its socio-economic challenges. However, the methods are not found to be effective to completely control this weed as are expected. This is could be attributed to the fact that each one of the aforementioned methods has its own limitation. The chemical methods cause environmental pollution whereas the physical methods are costly and not suitable for areas with very large infestations. The biological methods require long time and also may be not feasible to practice in most developing countries for several reasons such as lack of appropriate technology,

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commitment of community and economic capacity (Rachele and Andrew, 2013; Tewabe 2015; Adrian, 2017; Sharma and Chauhan, 2017; Worku and Shalie, 2018).

Reports revealed that this weed has been introduced into Ethiopia about sixty years ago (Daniel *et al*., 2011; Wonde, 2013; Tegene and Ayele, 2014; Firehun, 2014. Fessehaie *et al.*, 2005). Currently, the weed has created severe damages in water bodies of the country such as Lake Tana (Near Bahir dar city), Lake Abaya, Lake Koka, and drainage structure of the Wonjishoa and Metahara sugar factory (Taye *et al*., 2009; Tewabe, 2015; Ebro *et al*., 2017; Asmare, 2017; Bedilu *et al.,* 2017; Yigrem and Yohannes, 2019). The livelihoods of farming communities, who are living nearby water hyacinth infested water bodies, have been negatively affected. This is because it infests their farm lands that made farming and harvesting of crops difficult leading to a dramatic loss of crop productivity. The weed has also been found to decrease water quality, increases disease out breaks, reduce fish catch, and decline the diversity of aquatic life in these areas (Tewabe *et al*., 2017; Asmare, 2017). Taking the issue seriously, government and non-governmental organizations in Ethiopia looking for different methods to eliminate the weed from the infested areas (specifically in and around Lake Tana), and also to prevent its spread unaffected parts of the country. Physical method is being used widely in the area. In this method, removal of the weed is carried out by manual uprooting of the weed and harvesting using machine (Asmare, 2017). Though it is at its experimental stage, biological control method is also has been some attention (Firehun *et al*., 2013; Admas *et al*., 2017).

The aforementioned control methods have not yet been found effective and economical, at the expected level. It is, therefore, advisable to seek for economically feasible and effective methods (Jafari, 2010; Weiping, *et al*., 2018). One possible option is devising methods that would help utilize this invasive weed for beneficial purposes. Some of the several alternative methods that are being utilized to control the weed include using it as animal fodder (Aboud *et al*., 2005), compost (fertilizer) (Oyakawa *et al.*, 1970; Majid, 1986; Szczeck, 1999), for bio-gas production (Ali *et al*., 2004; Santos *et al*., 2018), waste water treatment (Ingole and Bhole, 2002; Noukeu, 2016), phytoremedation (Soltan and Rashed, 2003; Mahamadi and Nharingo, 2010) and for paper production (Goswami and Saikia, 1994; Pintor-Ibarra *et al*., 2018). So far, attempts made to control this weed found to be costly with minimum results. This has necessitated looking for other alternatives such as utilization of the weed for economic benefits. In the present study, the possibility of using water hyacinth as source of alkali solution for soap preparation was explored thinking that this approach could be potential control option. So, the lye solution of the ash of water hyacinth and used cooking oil samples were used to prepare soap materials. There are no literature reports on attempts to prepare soap from lye of ash of water hyacinth and used cooking oil samples.

2. Material and methods

2.1 Chemicals and reagents

Hydrochloric acid, alcoholic potassium hydroxide, phenolphthalein, ethanol, sulfuric acid, sodium chloride, potassium dichromate, carbon tetrachloride, iodine solution, glacial acetic acid, potassium iodide, sodium hydroxide, starch indicator and sodium thiosulphate were some of the chemicals/regents used in the experiment. All chemicals and/or reagents were general laboratory grade and were purchased from Ranchem PLT Co. agent, Addis Ababa, Ethiopia.

2.2 Collection oil samples and plant materials

The whole plant parts (leaves, roots and stems) were collected from Lake Tana, near Bahir Dar city, west Gojjam zone, Amhara Regional State, Ethiopia in April 2019. The plant material was dried completely by exposing it to a direct sunlight. The dried material was subjected to an open air burning to get ashes. Hotels, restaurants and street food venders were approached to obtain used cooking oil samples.

2.3 Lye solution preparation

A literature reported procedures (Zauro *et al*., 2016; Legesse *et al*., 2020; Legesse *et al*., 2021) were used to prepare the lye solution from the ash. This was done by boiling of sieved ash (150 g) with excess amount of distilled water for 30 minutes and continuous stirring. The hot solution was cooled to room temperature. The resulting cold solution was filtered using Whatmann No.1 filter paper. It was then heated on over water bath until a fresh egg floats and/or it maintains an alkalinity of pH range > 7.

2.4 Pre-treatment and determination of the properties of oil samples

The oil samples were subjected to pre-treatment process. The process involves heating to 60 ^{o}C followed by filtration (Umor, 2002). The pre-treated oils were then subjected for furthers analyses to test their properties such as

saponification values (SV), acid values (AV) and iodine values (IV) employing literature reported procedures. These were determined in order test suitability of the oils for saponification. All the measurements were made in triplicate, and the mean values of the measurements were taken to determine the aforementioned properties.

Saponification value (SV)

The SVs of the oil samples were determined by mixing 2 g of an oil sample with 25 ml of ethanolic KOH solution (0.5 M) in a conical flask of 200 ml capacity. The content of the flask was heated for 1 hr in water bath with a continuous stirring. Then it was cooled to room temperature. The cold mixture was subsequently titrated with hydrochloric acid (0.5 M) using phenolphthalein solution (1%) as an indicator. A blank titration was also performed likewise. Determination of SV determined using the formula given below (Eq. 1) (Hautfenne, 1982; AOCS, 1997; Atiku *et al*., 2014; Vivian *et al.,* 2014**;** Osagie and Enyi, 2015; Ashrafy *et al*., 2016**).**

$$\text{Saponification Value} = \frac{28.06 \times V}{W} \qquad \text{(Eq. 1)}$$

Where; V = Average volume of KOH in ml; W = Weight of an oil sample used for the test 28.06 = 0.5 x MW (56.1g/mol) of KOH

2.4.1 Acid value (AV)

The AVs were determined by boiling 2 g of oil samples with 100 ml of ethanol. Then 2-3 drops of indicator (phenolphthalein) were added into the cold mixture. The content of the flask was titrated with KOH solution (0.1 N) till the color of the mixture was turned pink. AVs were determined using the formula given below (Eq. 2) (Hautfenne, 1982; AOCS, 1997; Atiku *et al*., 2014; Vivian *et al.,* 2014**;** Osagie and Enyi, 2015; Ashrafy *et al*., 2016**).**

$$\text{Acid Value} = \frac{56.1 \times V \times N}{W} \qquad \text{(Eq. 2)}$$

- V = quantity KOH solution (titrant) used (in ml); N= Concentration of the standard KOH solution (in N)
- W = is the weight of an oil sample (in g); 56.1 is molecular weight of KOH (g/mol)

Iodine value (IV)

8 g of iodine was dissolved in 200 cm^3 glacial acetic acid to prepare the Wijs reagent. In another test tube, 9 g of iodine crystal was dissolved in 300 cm^3 carbon tetra chloride (CCl_4). Subsequently, an oil sample (10 g) was mixed with 10 cm^3 CCl_4 and 20 cm^3 of the prepared Wij's solution. The mixture was then allowed to cool by keeping it in a dark cup board for 30 minutes. Then, potassium iodide solution (15 ml) was added into the cold mixture followed by addition of 100 cm^3 of distilled water. Finally, a sample from the above mixture was titrated against sodium thiosulfate solution (0.1 M). In this experiment, starch was used as an indicator. A blank titration was also conducted under the same conditions. The IVs of the oil samples were determined using the formula given below (Eq. 3) (Hautfenne, 1982; AOCS, 1997; Atiku *et al*., 2014; Vivian *et al.,* 2014**;** Osagie and Enyi, 2015; Ashrafy *et al*., 2016**).**

$$\text{Iodine Value} = \frac{[(A-B)\times N\times 12.69]}{Q} \qquad \text{(Eq. 3)}$$

Where,

- A = volume (in ml) of 0.1 M $Na_2S_2O_3.5H_2O$ solution (0.1 M) used for blank titration.
- B = volume (in ml) of $Na_2S_2O_3.5H_2O$ solution (0.1 M) used for blank sample titration.
- Q = amount oil sample (in g)
- N = concentration of $Na_2S_2O_3.5H_2O$ solution (in N)
- 12.69 is the conversion factor from mEq of $Na_2S_2O_3.5H_2O$ to grams of iodine

2.5 Preparation of soap

To prepare the soap materials, oil sample (10 g), ethanol (30 ml) and lye solution (60 ml) were mixed in beaker of 500 ml Erlenmeyer flask. The content of the beaker was heated in a water bath at a temperature of 90°C. The heating was done for 50 minutes with a continuous stirring using a glass rod. The hot solution was added into a beaker that contained brine solution (50 ml). The mixture was stirred continuously in order to separate the soap mass from the glycerol and aqueous solution. The cold mixture was subjected to filtration using filter paper in order to separate the prepared soap product. Finally, the prepared soap material was dried in an oven and was kept in a dry place until it is used for physicochemical property tests as per the procedures reported in literatures (Legesse *et al*., 2020; Legesse *et al*., 2021).

2.6 Physicochemical properties of the soaps

After their preparation, the soap materials were subjected to physicochemical property tests. The properties were determined employing the procedures reported in literature reports. The tests were also carried out on the three commercial soap samples (references) namely Diva, Shemu and Coral. All the measurements were made in triplicates, and their mean values are presented in this paper.

2.6.1 Moisture content (MC)

The MC values of the prepared soap materials were determined using 5 g of soap sample (from each soap product) that was dried at 110°C. The MC values were determined by taking the ratio of mass changes to masses of the soap samples before drying (Eq. 4) (Hautfenne, 1982; Atiku *et al*., 2014; Vivian et al., 2014; Osagie and Enyi, 2015; Ashrafy et al., 2016).

$$\mathrm{MC} = \frac{[(Wi - Wf) \times 100\%}{Wi} \qquad \text{(Eq. 4)}$$

Where

- W*i* = weight of soap sample before drying;
- Wf = weight soap sample after drying

2.7 Total free alkali (TFA)

The TFA values of the prepared soap materials were determined by taking 10 g samples. Literature reported standard procedures were used in this experiment. The samples were mixed with 10 ml of neutralized ethanol in a beaker. Then 1N H_2SO_4 solution (5 ml) was added into the mixture. The content of each beaker was heated until the soap samples were completely got dissolved. The mixtures were allowed to cool to room temperature. The cold solutions were then titrated against NaOH solution (1N). Phenolphthalein was used as an indicator. The TFA was calculated using the following Equation (Eq. 5) (Hautfenne, 1982; Atiku et al., 2014; Vivian et al., 2014; Osagie and Enyi, 2015; Ashrafy et al., 2016).

$$\text{Total free alkali} = \frac{[(VA - VB) \times 3.1}{W} \qquad \text{(Eq. 5)}$$

Where,

- VA = volume of acid (in ml); VB = volume of base (in ml)
- W = weight of soap (in g); 3.1 = conversion factor

2.7.1 Total fatty matter (TFM)

The TFM values of the prepared soap materials were determined by treating them with acid in the presence of hot ethanol. This test was conducted by adding 10 g of soap sample into 500-ml flask that contained 150 ml of warm neutralized ethanol. The content of each flask was heated until the soap sample was dissolved completely. The solution was allowed to cool to room temperature and filtered using a filter paper. The residue was made to dry in an oven (at 110°C) for 1 hour. The TFM value each soap sample was determined using the following Equation (Eq. 6) (Hautfenne, 1982; Atiku et al., 2014; Vivian et al., 2014; Osagie and Enyi, 2015; Ashrafy et al., 2016).

$$TFM = \frac{100-(MC-MIA)}{1.085} \quad \text{(Eq. 6)}$$

Where,

- MC = Moisture content of the prepared soap
- MIA = Matter insoluble in alcohol
- 1.085: conversion factor

2.8 Matter insoluble in alcohol (MIA)

The MIA values of the prepared soaps were determined by taking 5 g sample from each product. In the experiment, each soap sample was dissolved using 50 ml ethanol. The mixture was poured onto a filter paper that was pre-weighed for the purpose of filtration. The resulting residue was dried by heating it in an oven at temperature of 105°C for 30 minutes. The residue was let to stand until its temperature was dropped to room temperature, and was subsequently weighed again. The MIA value each soap sample was calculated using the formula given below (Eq. 7) (Hautfenne, 1982; Atiku et al., 2014; Vivian et al., 2014; Osagie and Enyi, 2015; Ashrafy et al., 2016).

$$MIA = \frac{(Ws-Fp)\times 100}{W} \quad \text{(Eq. 7)}$$

Where,

- Ws = Weight of soap sample + filter paper
- FP = Weight of filter paper
- W = Weight of the soap sample

2.8.1 pH value

The pH values of the soap products were determined by taking 10 g sample from each product. In the course of the experiment, 100 ml of distilled water was used to dissolve the soap samples completely. The pH value each of the solution was measured using a calibrated pH meter (Hautfenne, 1982; Atiku et al., 2014; Vivian et al., 2014; Osagie and Enyi, 2015; Ashrafy et al., 2016).

2.8.2 Cleaning action and foaming ability of the soap samples

Sufficient amount of distilled water was used to dissolve the soap samples (2 g). The resulting solution was used to test the cleaning abilities of the prepared soaps. A cloth that was stained with oil was used for the cleaning test. The foam of the soap solution (500 ml) was taken in a conical flask. The solution was shaken vigorously for 2 minutes to generate foam. Then the foam was let to stand and then its stability was determined as per literature reports (Legesse, 2020; Legesse *et al*., 2020).

3. Results and discussion

It is a well-known fact that soaps are prepared by boiling animal fat or vegetable oil with alkaline solutions (E.g., NaOH and/or KOH solution) using the process known as saponification. Literature reports showed that alkaline solutions obtained from ashes of agricultural wastes and weeds (Mistral *et al*., 1993; Ogunsuyi and Akinnawo, 2012; Oluremi *et al*,. 2012; Beetseh and Anzo, 2013; Atiku *et al*, 2014) and used cooking oils can also be used as inputs to prepare soaps of acceptable qualities (Legesse, 2020; Legesse *et al*., 2020). This has two purposes; substitute for commercial inputs and pollution control caused by used cooking oils and weeds (Malaysia, 2015).

3.1 Preparation of lye solutions

Ashes of plant materials are used for preparation of lye solution that mainly containing KOH or NaOH for soap preparation (Ogunsuyi and Akinnawo, 2012). Alkalinity of the prepared lye solution was tested using a phenolphtelien indicator that changes to pink, and also red litmus paper turned to blue and pH paper. The color changes indicated the alkaline nature the prepared solution revealed its. The pH (10.85) of the solution also confirmed the alkalinity. The

finding is also consistent with the literature reported basicity of lye solution prepared from the ash of parthenium weed (Legesse *et al.,* 2021) and jatropha (Legesse *et al*., 2020).

3.1.1 Physiochemical properties of oil samples

The physiochemical properties of the oil samples namely saponification value (SV), Acid value (AV) and Iodine value were analyzed using standard methods in order to evaluate whether they could qualify for soap making or not.

3.2 Saponification value (SV)

SV is a parameter that refers the number of milligrams of KOH or NaOH required to saponify 1 gram of oil or fat (Shahidi, 2005; Warra, 2013). Literature reports also indicated that an oil sample with high SVs, for instance, from coconut oil (257.0 mgKOH/g) and palm oil (199.1 mgKOH/g) to show good quality for soap making (FAO, 2015). In the present study, the SVs were found to be 157.08 ± 0.07 mgKOH/g (for oil sample from street food venders), 197.75 ± 0.40 mgKOH/g (oil sample from hotels) and 198.80 ± 0.65 mgKOH/g (oil samples from restaurants) (Table 1). The observed SV data and comparison with literature reports (FAO, 2015) indicated that the oils samples used in the study possess the acceptable qualities for laundry soap making (Legesse, 2020).

Table 1 The physicochemical properties of the oil samples used in the study

Source of used cooking oil samples	SV (mg KOH/g)	AV (mg KOH/g)	IV (gI_2/g)
Street food venders	157.08 ± 0.07	15.87 ± 0.3	33.63 ± 0.82
Hotels	197.75 ± 0.40	11.22 ± 0.08	29.2 ± 0.53
Restaurants	198.80 ± 0.65	11.06 ± 0.01	28.75 ± 0.92

SV: Saponification value; **AV**: Acid value; **IV:** Iodine value

3.3 Acid value (AV)

AV is one of the commonly used parameters to assess quality of oil in soap preparation. It refers to the number of milligrams of KOH needed to neutralize free fatty acid present in one gram of oil or fat. Lower AV values to indicate occurrence of fewer fatty acids. Thus, such oils or fats are less susceptible to rancidity (Mabrouk, 2005; Warra, 2013). The AV results obtained in this study are 15.87±0.3 mg KOH/g, 11.22±0.08 mg KOH/g and 11.06±0.01 mg KOH/g for oil samples obtained from street food venders, hotels and restaurants, respectively (Table 2). The observed AVs showed that the oil samples from hotels and restaurants were slightly lower than literature reported value (15 mg KOH/g). But the corresponding value for oil collected from street food vender (15.87 ± 0.3 KOH/g) was comparable to the standard value reported in literature (Umor, 2002). It is, therefore, worthwhile to prepare soaps and check the quality by using each oil type.

3.4 Iodine value (IV)

IV is one of the important parameters to assess qualities of oil samples before using them for soap making. It refers to the amount of iodine in grams taken up by 100 g of oil/fat sample. Its value also indicates the amount of unsaturated fatty acids present in a given oil product. Low IVs indicate the presence of fewer unsaturated fatty acids in oil. Thus oils with low IVs will have low rate of rancidity or oxidation, and are used for making harder soap bars (Hautfenne, 1982; Phanseil *et al*., 1998; Debash, 2013; Atiku, *et. al.;* 2014). The IVs of the used cooking oil samples were in the range of 28.75±0.92 -33.63±0.82 g I_2/g (Table 1). These values are lower than IV value reported for palm oil (52.63 ± 0.14) that is commonly used for soap making (Azmil et al., 2008). This, therefore, suggests that the oil samples used in the study have fulfilled the minimum requirements for soap making.

3.5 Preparation of soap

Soap can be produced by boiling vegetable oil/animal fat with alkaline (lye) solutions that usually contain either NaOH or KOH by a process known as saponification (Beetseh and Anzo, 2013; Warra, 2013). Commonly used alkaline compounds, for soap making, are of commercial origin, and are obtained from industrialized nations. This makes the cost of soaps very high in developing countries such as Ethiopia. Thus, use of locally available materials such as ashes of agricultural residues and weeds can be used as a means to prepare alkaline solution for soap making (Osagie and Enyi, 2015; Undiandeye, 2015; Zauro1 *et al.,* 2016; Waithaka and Muriuki, 2019) and controlling environmental pollution, at the same time.

In the present study, alkaline solution was prepared from ash of water hyacinth weed. As it is mentioned in the introduction part, this weed is available in abundance in some of the Ethiopian lakes. It is spreading rapidly causing water pollution. The prepared soaps are soft (paste-like) that are not solidified immediately upon addition of brine solution (Figure 1). This might be due to larger potassium oxide proportion (as compared to sodium hydroxide) in the ash of water hyacinth (Atiku, 2014; Okoye *et al*.; 2015; Undiandye *et al*., 2015; Lara, 2016; Shafy, 2016; Tony, 2016). Potassium-based soaps are usually liquid or soft soaps as they are difficult to separate them from the lye solution due to their high solubility (Nelson, 1948).

3.6 Physicochemical properties of the prepared soaps

Some physical properties of the prepared soap materials that were prepared using standard procedures reported literatures (Beetseh and Anzo, 2013) are briefly discussed in this section. Three commercial soap samples (Diva, Shemu and Coral) were purchased from local markets in Hawassa city, and their properties were determined for the sake of comparison of data obtained from the experiments.

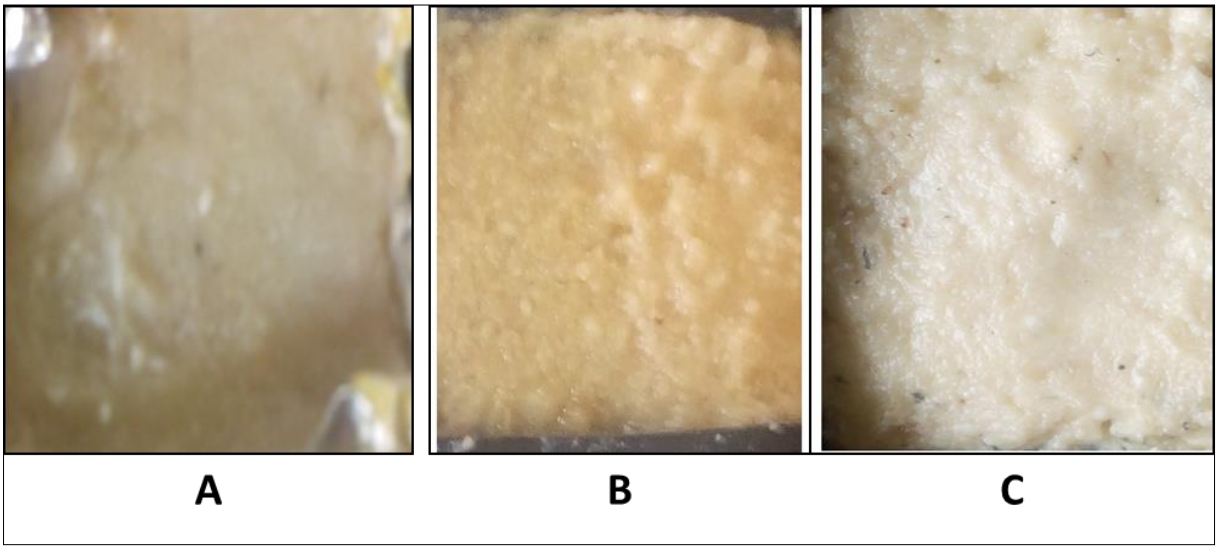

Figure 1 The soaps prepared using oil samples collected from street food venders (A), hotels (B) and restaurants oils (C) and a lye solution obtained from water hyacinth (Kefale Firew, 2019)

3.7 Moisture content (MC)

Table 2 The physicochemical properties of soaps prepared in this experiment

Soap prepared from	MC (%)	TAC (%)	(%)	pH value	Cleaning ability	Foam ability
Used oil from hotels	24.3	0.84	68.2	10.33	Good	Good
Used oil from street food venders	37.8	0.46	72.8	10.21	Good	Good
Used oil from restaurants	29.2	0.77	69.5	9.82	Good	Good
Commercial soap						
Diva	8.25 ± 0.91	0.94 ± 0.03	75.26 ± 0.26	10.32	Excellent	Very good
Coral	6.45 ± 1.2	1.01 ± 0.05	77.02 ± 0.41	10.53	Very good	Good
Shemu	5 ± 0.85	0.92 ± 0.017	75.91 ± 0.20	10.68	Very good	Excellent

MC: Moisture Content; **TAC:** Total alkali content; **TFM:** Total fatty matter

The MC value of a soap product refers to the existence of liquid traces of water molecule in an oil sample. It is used in predicting the shelf-life of a soap product. Literature reports state that high MC value of a soap product would result in

a reaction of excess water with unsaponified fat to give free fatty acid and glycerol. Such hydrolyses reaction would make it difficult to store soap products for long period of times. It is determined by dissolving the soap sample in distilled water and drying it in an oven at 110^{o}C (Hautfenne, 1982). The MC values for soaps from used cooking oils, oils from hotel, oils from restaurants and oils from street food venders, respectively are 24.3%, 29.2% and 37.8% (Table 2). The observed MC values of the soaps were found to be relatively high, and were found to be higher than the corresponding values of the commercial soaps namely Diva (8.25 ± 0.91%), Coral (6.45 ± 1.2%) and Shemu (5 ± 0.85%) used in the study(Table 2). It, however, is comparable with moisture content of potassium soaps reported in literature (15 to 22%) (USA patent, 1956) and that of liquid soaps from Ghana (16-46%) (Doreen *et al*., 2014). The MC value also indicates that the prepared soaps are potassium soaps and in the limits of the MC ranges of liquid soaps.

3.8 Total free alkali content (TFA)

The TFA content is a physicochemical property that refers the quantity of free caustic alkali and carbonated alkali. It is expressed as a percentage (m/m) as either NaOH for sodium soaps or KOH for potassium soaps (Hautfenne, 1982). The TFA contents of the soaps prepared in this study were 0.84, 0.77 and 0.46% for soaps prepared using used oil samples collected from hotels, restaurants and street food venders, respectively (Table 2). The values were found to be comparable with the reported TFA values of commercial soaps (Coral 1.01 ± 0.05%, Shemu 0.92 ± 0.017% and Diva 0.94 ± 0.03% <5%) used in the study. They, however, are lower than the International Organization for Standardization (ISO) specification (< 2%) (Legesse, 2020). This shows that the TFA values of the prepared soaps from the ash of water hyacinth weed to be the acceptable limit of ISO.

3.9 Total fatty matter (TFM)

One of the most important characteristics that describe quality of a soap product is TFM. Soap products with high content of TFM indicate that a given soap product has a better quality. The TFM is used to quantitatively describe amount of fatty matter (fatty acids) in soap products. The fatty matter commonly present in soaps are oleic, steric and palmitic acids. The TFM data in this study were found to be 68.2%, 72.8% and 69.5% for soaps prepared from oil from hotel, oils from restaurants and oils from street food venders, respectively (Table 2). The corresponding values were 75.26 ± 0.26%, 77.02 ± 0.41% and 75.91 ± 0.20% for the commercial soaps namely Diva, Shemu and Coral, respectively (Table 4). The observed TFM values are higher than the minimum requirement reported by East African Standards (50%) (EAS, 2014), and are comparable with the TFM value (34-75%) reported by Beetseh and Anzo, (2013). The TFM value less than 50% indicates that a soap product associated with hardness and lower quality (ISO, 2013). Accepted limits TFM values are different from country to country. For instance, soap products referred as grade I, grade II and grade III if TFM values ≥ 75%, minimum TFM value of 65% and TFM value above > 50%, respectively (BIS, 2011; ISO, 2013). The observed TFM data in the present study indicated that the prepared soaps are of good grade soaps.

3.10 The pH value

This is an important property that needs to be determined before marketing soap products to human use as it measures alkalinity of soap products. A given soap product with pH 9-11 is considered as suitable product for human use. Soap should not cause harmful effects on skin and hands when it is used for cleaning (Gunathilake *et al*., 2007; Tarun *et al*., 2014). The data in this experiment were comparable to each other and also to that of the three commercial soaps used in the study (Table 2). The values, moreover, were found to be in line with recommended pH range (9-11) of commercial soap products (Lumley and Colwell, 1991; Viorica,, *et al*., 2011; Warra, 2013; Tarun *et al*., 2014; Vivian *et al*., 2014). The data suggested that the prepared soaps could be used for cleaning purpose without causing any harm on users' skin.

3.11 Cleaning ability test of the prepared soap products

The quality of a soap product can be measured by its ability to clean dirt materials (Hui, 1996). Although this property is subjective, the result of our study is presented by comparing the prepared soap cleaning ability with the commercial soaps. In this study, the prepared soaps showed comparable cleaning ability to each other and a slightly lesser extent to that of the commercial soaps products (Diva, Shemu and Coral) (Table 2). In general, the finding of the present study indicated that soaps produced from the lye solution obtained from the ashes of water hyacinth and used cooking oils are in the acceptable quality soap grade. The finding of this study indicated that use of water hyacinth ash for lye preparation could be considered as an alternative method to control environmental pollution caused by the weed.

3.12 Foaming ability and stability test

Literature reports reveal that fatty acid compositions of oil used for preparation soap products are used to explain the soaps' ability in lather formation. For instance, lauric and mystric acids are saturated fatty acids and are used to produce soaps with fluffy leather (Hui, 1996; El-Sharkawy, 2011; Siva *et al*., 2015). The result of the foaming ability and stability

test indicates the prepared soaps form good and sufficiently stable lather (Table 2). The observed lather and its stability were found to be comparable with similar properties of the commercial laundry soap samples (Diva, Shemu and Coral) (Table 2) used in the study. The observed slight differences in foaming abilities and leather stability could be attributed to the presence of foaming agents that enhance foam formation in commercial soaps and absence of such agents in the prepared soaps (Bajpai and Tyagi, 2007; Chen *et al*., 2010).

4. Conclusion

The lye solution prepared from water hyacinth showed enough basicity (9.82-10.13) and the physicochemical properties of the used cooking oils also revealed that they have sufficient qualities to be used as inputs for soap making. The properties (MC, TFM, TAC, pH, foaming stability and cleaning abilities) of the prepared soaps were also found to be in the ranges of reported standards of laundry soaps. Therefore, the prepared soaps are believed to be sufficiently useful for cleaning purposes indicating the possibility of water hyacinth weed ash for making liquid/soft soap substituting the commercial/imported potassium hydroxide. This would also serve as a means to control the invasion of the lakes (such as Lake Tana) in Ethiopia by water hyacinth, simultaneously. These days small scale soap production is flourishing in Ethiopia. The result of the study can, therefore, also be considered as a potential area in creating job opportunity to the local community where the weed grows in abundance.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflicts of interest have been declared.

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