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A comparison of the antibacterial activity of some African black soaps and medicated soaps commonly used for the treatment of bacteria-infected wound

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Background: Black soap is a medicinal product that could be harnessed for economic purpose if properly packaged, and misconception about its traditional use by herbalists is thrown overboard.

Aims: To promote the relevance of these soaps for economic development, this study compared the antibacterial activity of black soaps with medicated soaps widely used against bacterial infections.

Methods: The antibacterial activities of these soap samples were determined by agar diffusion and macrobroth dilution methods.

Results: In this study, the statistical analysis of the inhibition zones showed that black soaps were significantly ($p < 0.05$) more active than medicated soaps used against the test bacterial isolates. The black soaps inhibited and killed the isolates better than the medicated soaps at the different concentrations used. The minimum inhibitory concentration for *Klebsiella pneumoniae* and *Enterococcus faecalis* ranged between 0.125 mg/mL and 2 mg/mL, *Staphylococcus aureus* (0.25–4) mg/mL, *Escherichia coli* (0.125–4) mg/mL and *Pseudomonas aeruginosa* (1–4) mg/mL. The result showed that *K. pneumoniae* and *E. faecalis* were the most susceptible, followed by *E. faecalis* > *E. coli* > *S. aureus* > *P. aeruginosa*.

Conclusion: As a valuable medicinal output derivable from organic waste product that could be converted to wealth, African black soap production, utilisation and commercialisation have tremendous economic potentials. These soaps showed significant antibacterial activity greater than those of the medicated soaps. Hence, their use could be a better option in place of commercially available medicated and antiseptic soaps because of the degree of antibacterial activities they exhibited.

Introduction

Soap may be defined as a chemical compound resulting from the interaction of fatty acids, oils and salt (Friedman & Wolf 1996). It is a cleaning agent made by the chemical action of alkali on fats or fatty acids to yield the sodium or potassium salts of these acids (Considine 1974). It possesses properties that may include wetting and emulsifying power, surface tension lowering and gel formation as well as acting as both active medication and vehicle for the incorporation of other active substances (Grayson 1983). In the treatment of skin diseases, it causes cooling, drying, hydration, crust and scale removal (Schwartz 1979). Although bacteria that attack human body are of great importance with reference to health, Fuls et al. (2008) reported the inhibitory potential of antimicrobial and non-antimicrobial soaps in clinical cases. Larson et al. (1987) and Toshima et al. (2001) indicated that soaps containing antimicrobial active ingredients could remove more bacteria as compared to plain soap, and Osborne and Grube (1982) had earlier reported that antibacterial containing soaps can remove 65% to 85% bacteria inhabiting human skin. When used properly, washing with soap could reduce *Propiobacterium acnes* and prevent secondary infections in acne skin (Kuehl et al. 2003) and healthcare-associated transmission of contagious diseases more effectively (Arya et al. 2005).

In ethnomedicine, described as total combination of knowledge, practice and belief incorporating plants, animals and minerals based medicine in diagnosing, preventing or eliminating a physical, mental or social disease and which may rely exclusively on past experience handed down from generation to generation either verbally or in writing (Sofowora 1982; Summers 2016), the use of soaps as vehicles for the application of medicinal plants for external use and in the treatment of skin diseases has been reported (Ahmed et al. 2005; Ajaiyeoba et al. 2003; Ajose 2007) because

locally manufactured soaps have some antimicrobial properties (Adebiyi 1980; Lamikanra & Allwood 1977; Moody et al. 2004). For centuries, the traditionally manufactured black soap, otherwise known as 'African black soap', has been used, in Ghana and Nigeria, to help relieve acne, oily skin, clear blemishes and various other skin issues. Black soap has been employed to get rid of skin rashes, ringworm, measles and body odours (Adelakun 1990) and for treating many infections caused by microorganisms as well as for exfoliating and deep cleansing (Underwood 2008). Although it is full of vitamins and emollients perfect for cleansing deeply, exfoliating gently and moisturising thoroughly, it is hypoallergenic and a great choice for those prone to skin rashes (Ukatta 1991). It also has the ability to emulsify grease and oil that hold dirty particles (Sharma 2006). Having antiseptic properties and being a natural shampoo to avoid dry itchy scalp, it is good for showering, bathing, washing hair and faces and helps keep the skin clear of premature facial lines.

In Africa, traditionally manufactured soap, otherwise known as African black soap, is known by different names from various regions. In Ghana, black soap is known as 'Anago soap' or 'Alata samina'. In Nigeria, it is known by the Hausas as 'Sabilum-salo', the Yorubas call it 'Ose-dudu' or 'abuwe' and the Igbos name it 'Ncha-Nkota' (Aliyu et al. 2012; Bella 2011; Getradeghana 2000; Summers 2016). African black soap is a natural source of vitamins A and E and iron (Grieve 1997). It is made of a combination of water, roasted plantain skin or cocoa pod, palm oil, palm kernel oil or shea butter. These are common oils used for the production of soap through saponification reactions (Kubmarawa & Atiko 2000). Depending on where it is manufactured, black soap contains leaves and bark from plantains, shea tree, cocoa pods or palm tree leaves. The leaves and bark are sun dried before being roasted slowly in a pot after which different oils including coconut oil, shea butter and palm kernel oil giving antimicrobial properties to the soap are added to the mixture (Getradeghana 2000). The soap mixture is then allowed to cool for at least 2 weeks before it is ready for use. Black soap made with shea butter offers protection against UV rays, whereas black soap made with plantains contains a high concentration of iron along with vitamins A and E (Underwood 2008). Although the ingredients and process can change depending on the area, its methods of preparation have been passed down from generation to generation to keep the soap close to Mother Nature and avoid exploitation and imitation (Sofowora 1982; Summers 2016).

Although the active ingredients in most antibacterial soaps are often listed on the packaging, quantitatively, those of traditionally manufactured soaps are unknown. Consequently, the therapeutic potentials of these black soaps have become inconsequential, probably because of its manufacturing procedures, packaging and misconception about its use by the traditional herbalists and its being indigenous. However, because of its ethnotherapeutic applications in the treatment of skin infections, wounds and the daily intake of its lather solution mixed with other plant extracts for detoxification, it becomes essential to investigate its antibacterial activities in comparison with those of some medicated soap with antibacterial properties commonly sold. Hence, this study was aimed at comparing the antibacterial activity of black soap samples obtained from south-west Nigeria with three medicated soaps used worldwide against five selected bacterial isolates implicated in wound infections.

Materials and methods

Collection of samples

Ten African black soap samples usually made from locally harvested and dried plant materials such as cocoa pods, plantain peels, palm tree leaves and shea butter tree bark were collected from 10 different towns in south-west Nigeria, whereas three antibacterial soaps, Dettol, Trichlorophenylmethyliodosalicyl (TCP) and Tetmosol, were purchased from a pharmacy outlet.

Test microorganisms

Five bacterial strains including *Pseudomonas aeruginosa* ATCC 19582, *Staphylococcus aureus* ATCC 6538, *Escherichia coli* ATCC 25922, *Klebsiella pneumoniae* ATCC 10031 and *Enterococcus faecalis* ATCC 19582 obtained from the Department of Biochemistry and Microbiology, University of Fort Hare, Alice, South Africa, were used for this study.

Antibiotic susceptibility testing using agar diffusion method

Each of the isolates was standardised using colony suspension method (EUCAST 2000). Each strain's suspension was matched with 0.5 McFarland standards to give a resultant concentration of 1.0×10^6 cfu/mL. The susceptibility of the different isolates to the different soap samples was determined using the modified Kirby–Bauer diffusion technique (Cheesbrough 2002) by swabbing the Mueller–Hinton agar (MHA) (Oxoids UK) plates with the resultant saline suspension of each strain. Wells were then bored into the agar medium with a heat sterilised 6-mm cork borer. The wells were filled with 100 µL of different concentrations (3.5 mg/mL, 7.0 mg/mL, 14.0 mg/mL, 28.0 mg/mL and 32 mg/mL) of each soap sample prepared taking care not to allow spillage of the solutions onto the surface of the agar. The plates were allowed to stand for at least 30 min before being incubated at 37°C for 24 h (BSAC 2013). The determinations were done in duplicate. After 24 h of incubation, the plates were examined for zones of inhibition (Bauer et al. 1996). The diameters of the inhibition zones produced by each soap sample were measured and interpreted using the CLSI zone diameter interpretative standards (CLSI 2015).

Minimum inhibitory concentrations (MICs) are important in diagnostic laboratories to confirm resistance of microorganisms to an antimicrobial agent and to monitor the activity of new antimicrobial agents. The susceptibility of the selected bacterial strains to each soap sample and their MICs were determined in duplicate by the standard macrobroth

dilution method in Mueller–Hinton broth (CLSI 2002; Wiegand et al. 2008). To determine the MICs of each soap sample, different concentrations ranging from 0.5 mg/mL to 16 mg/mL were prepared by serial dilution in double strength Mueller–Hinton broth. The tubes were inoculated with 100 µL of each of the bacterial strains. Blank Mueller–Hinton broth was used as negative control. The bacteria-containing tubes were incubated at 37°C for 24 h. Each assay was performed two times. The MIC was defined as the lowest soap concentrations that showed no growth in the Mueller–Hinton broth.

Determination of minimum bactericidal concentrations

The minimum bactericidal concentrations (MBC) assay was carried out as described by Cheesbrough (2006). Here, fresh nutrient agar plates were inoculated with one loopful of culture taken from each of the broth cultures that showed no growth in the MIC tubes. The plates were incubated at 37°C for 24 h. After the incubation period, the lowest concentration of the extract that did not produce any bacterial growth on the solid medium was regarded as MBC values for these soap samples (Irkin & Korukluoglu 2007). This observation was matched with the MIC test tube that did not show evidence of growth after 48 h of incubating the bacterial cultures.

Determination of mechanisms of antibiosis (bactericidal or bacteriostatic)

The MBC is the lowest concentration of antimicrobial agents required to kill a particular bacterium. The mechanism of antibiosis of the soap samples was calculated using the ratio of MBC or MIC or MIC_{index} as described by Shanmughapriya et al. (2008) to elucidate whether the observed antibacterial effects were bactericidal or bacteriostatic. Although antimicrobials are usually regarded as bactericidal if the MBC is no more than four times the MIC (French 2006), when the ratio of MBC or MIC was ≤ 2.0, the soap samples were considered bactericidal or otherwise bacteriostatic. If the ratio was ≥ 16.0, the extract was considered ineffective.

Statistical analysis

All the data were subjected to one-way analysis of variance (ANOVA), and the mean values were separated at $p < 0.05$ using Duncan's multiple range test. The one-way ANOVA test was used to determine if there was any statistically significant difference in the inhibition zones of each bacterial isolate produced by each soap sample. All statistical analyses were done using SPSS software (2009).

Results

The resulting zones of inhibition from the different soap samples were compared statistically and are presented in Table 1. From this study, the black soap samples from different sources were able to inhibit the growth of the test bacterial isolates in the different concentrations used. The antibacterial activities were concentration dependent in all the black soap samples except for those of the selected antibacterial medicated soaps that were slightly active at their highest concentrations. Comparatively, the statistical analysis of the inhibition zones showed that each black soap sample was significantly more active than each of the selected antibacterial soaps against the selected test bacterial strains. Although the antibacterial activities of OYN6, OYN7 and OYN8 were not significantly different from those of OYN3, OYN4 and OYN5, the antibacterial activities of most of the other black soaps were significantly different from each other. Although 66.67% of the samples compared exhibited significantly different antibacterial activities, 33.33% of the samples were not significantly different in their antibacterial activities. With the exception of OYN8, OYN9 OYN10 which produced inhibition zones equal to 20 mm ± 1.0 mm in *E. faecalis*, 100 µL of the highest concentration of 32 mg/mL of all the black soap samples produced inhibition zones greater than 20 mm ± 1.0 mm from all the other organisms. Although *K. pneumoniae* was the most susceptible to OYN1, OYN2, OYN3 and OYN4 samples, *E. faecalis* was the most susceptible to OYN2, OYN6 and OYN7, *E. coli* was the most susceptible to OYN9 and OYN10, and *S. aureus* and *P. aeruginosa* had their highest inhibition zone from OYN5. Although all the black soap samples were effective against the bacterial isolates at the different concentrations used, 100 µL of 24 mg/mL of the antibacterial medicated soap samples was the only concentration effective against the bacterial isolates (Figure 1). The largest inhibition zones were obtained in the black soaps compared to the medicated antibacterial soaps showing no zone of inhibition at different concentrations.

To establish the degree of antibacterial activities of the different soap samples, their antibacterial activities were further investigated by macrobroth dilutions to determine the MIC and MBC. The resulting MIC and MBC are summarised in Figure 2. The MIC for *K. pneumoniae* and *E. faecalis* ranged between 0.125 mg/mL and 2 mg/mL, for *S. aureus* ranged between 0.25 mg/mL and 4 mg/mL, for *E. coli* ranged between 0.125 mg/mL and 4 mg/mL and for *P. aeruginosa* ranged between 1 mg/mL and 4 mg/mL. The result showed that *K. pneumoniae* was the most susceptible, followed by *E. faecalis* > *E. coli* > *S. aureus* > *P. aeruginosa*. The MIC_{index} indicating whether the antibacterial activities of the black soaps were bactericidal or bacteriostatic showed that the activities of the soap samples were mostly bactericidal. Although the MBCs were higher than the MICs, the differences in the MICs and MBCs showed the black soaps to have a selective antibacterial activity. That the MBCs were not more than four times the MICs in most cases and MIC_{index} was mostly equal to 2 showed that the black soap samples have bactericidal effects.

Discussion

In time past, the cosmetic, toiletry and pharmaceutical industry had a selection of fewer than 100 plant preparations from which to choose. However, prior to the advent of this industry, the ethnotherapeutic application of ethnomedicine by local people, including the use of African

TABLE 1: Comparative analysis of the inhibition zones produced by the different soap samples.

Pair	Sample codes	Mean	Std. deviation	Std. error mean	95% Confidence interval of the difference		*t*	df	Sig (2-tailed) $P < 0.05$	Decision
					Lower	Upper				
Pair 1	OYN1 - OYN2	-3.16667	3.25982	0.59516	-4.38390	-1.94943	-5.321	29	0.000	Reject H0
Pair 2	OYN1 - OYN3	-2.80000	3.06707	0.55997	-3.94526	-1.65474	-5.000	29	0.000	Reject H0
Pair 3	OYN1 - OYN4	-2.46667	3.18112	0.58079	-3.65452	-1.27882	-4.247	29	0.000	Reject H0
Pair 4	OYN1 - OYN5	-2.30000	3.36462	0.61429	-3.55637	-1.04363	-3.744	29	0.001	Reject H0
Pair 5	OYN1 - OYN6	-2.00000	3.95666	0.72238	-3.47744	-0.52256	-2.769	29	0.010	Reject H0
Pair 6	OYN1 - OYN7	-2.43333	3.24498	0.59245	-3.64503	-1.22164	-4.107	29	0.000	Reject H0
Pair 7	OYN1 - OYN8	-1.80000	3.44814	0.62954	-3.08756	-0.51244	-2.859	29	0.008	Reject H0
Pair 8	OYN1 - OYN9	-0.80000	3.08947	0.56406	-1.95363	0.35363	-1.418	29	0.167	Accept H0
Pair 9	OYN1 - OYN10	-1.30000	3.89651	0.71140	-2.75498	0.15498	-1.827	29	0.078	Accept H0
Pair 10	OYN1 - OYN11	13.56667	5.76364	1.05229	11.41449	15.71885	12.892	29	0.000	Reject H0
Pair 11	OYN1 - OYN12	12.73333	5.97658	1.09117	10.50164	14.96503	11.669	29	0.000	Reject H0
Pair 12	OYN1 - OYN13	12.10000	6.60381	1.20569	9.63410	14.56590	10.036	29	0.000	Reject H0
Pair 13	OYN2 - OYN3	0.36667	2.14127	0.39094	-0.43290	1.16623	0.938	29	0.356	Accept H0
Pair 14	OYN2 - OYN4	0.70000	1.85974	0.33954	0.00556	1.39444	2.062	29	0.048	Reject H0
Pair 15	OYN2 - OYN5	0.86667	1.90703	0.34818	0.15457	1.57877	2.489	29	0.019	Reject H0
Pair 16	OYN2 - OYN6	1.16667	2.85371	0.52101	0.10107	2.23226	2.239	29	0.033	Reject H0
Pair 17	OYN2 - OYN7	0.73333	2.01603	0.36807	-0.01946	1.48613	1.992	29	0.056	Accept H0
Pair 18	OYN2 - OYN8	1.36667	2.79758	0.51077	0.32203	2.41130	2.676	29	0.012	Reject H0
Pair 19	OYN2 - OYN9	2.36667	3.60539	0.65825	1.02039	3.71294	3.595	29	0.001	Reject H0
Pair 20	OYN2 - OYN10	1.86667	3.52071	0.64279	0.55201	3.18132	2.904	29	0.007	Reject H0
Pair 21	OYN2 - OYN11	16.73333	4.74838	0.86693	14.96026	18.50641	19.302	29	0.000	Reject H0
Pair 22	OYN2 - OYN12	15.90000	5.26111	0.96054	13.93547	17.86453	16.553	29	0.000	Reject H0
Pair 23	OYN2 - OYN13	15.26667	6.00536	1.09642	13.02423	17.50911	13.924	29	0.000	Reject H0
Pair 24	OYN3 - OYN4	0.33333	1.44636	0.26407	-0.20675	0.87341	1.262	29	0.217	Accept H0
Pair 25	OYN3 - OYN5	0.50000	1.73702	0.31714	-0.14861	1.14861	1.577	29	0.126	Accept H0
Pair 26	OYN3 - OYN6	0.80000	2.05779	0.37570	0.03161	1.56839	2.129	29	0.042	Reject H0
Pair 27	OYN3 - OYN7	0.36667	2.09241	0.38202	-0.41465	1.14798	0.960	29	0.345	Accept H0
Pair 28	OYN3 - OYN8	1.00000	1.66091	0.30324	0.37981	1.62019	3.298	29	0.003	Reject H0
Pair 29	OYN3 - OYN9	2.00000	2.82843	0.51640	0.94385	3.05615	3.873	29	0.001	Reject H0
Pair 30	OYN3 - OYN10	1.50000	1.99569	0.36436	0.75480	2.24520	4.117	29	0.000	Reject H0
Pair 31	OYN3 - OYN11	16.36667	4.52947	0.82696	14.67534	18.05800	19.791	29	0.000	Reject H0
Pair 32	OYN3 - OYN12	15.53333	4.87593	0.89022	13.71263	17.35404	17.449	29	0.000	Reject H0
Pair 33	OYN3 - OYN13	14.90000	5.42249	0.99001	12.87521	16.92479	15.050	29	0.000	Reject H0
Pair 34	OYN4 - OYN5	0.16667	1.59921	0.29197	-0.43049	0.76382	0.571	29	0.573	Accept H0
Pair 35	OYN4 - OYN6	0.46667	2.04658	0.37365	-0.29754	1.23087	1.249	29	0.222	Accept H0
Pair 36	OYN4 - OYN7	0.03333	1.47352	0.26903	-0.51689	0.58356	0.124	29	0.902	Accept H0
Pair 37	OYN4 - OYN8	0.66667	1.78757	0.32636	-0.00082	1.33416	2.043	29	0.050	Accept H0
Pair 38	OYN4 - OYN9	1.66667	2.53708	0.46321	0.71930	2.61403	3.598	29	0.001	Reject H0
Pair 39	OYN4 - OYN10	1.16667	2.18274	0.39851	0.35162	1.98172	2.928	29	0.007	Reject H0
Pair 40	OYN4 - OYN11	16.03333	4.49891	0.82139	14.35341	17.71326	19.520	29	0.000	Reject H0
Pair 41	OYN4 - OYN12	15.20000	4.80230	0.87678	13.40679	16.99321	17.336	29	0.000	Reject H0
Pair 42	OYN4 - OYN13	14.56667	5.55650	1.01447	12.49183	16.64150	14.359	29	0.000	Reject H0
Pair 43	OYN5 - OYN6	0.30000	1.95024	0.35606	-0.42823	1.02823	0.843	29	0.406	Accept H0
Pair 44	OYN5 - OYN7	-0.13333	1.52527	0.27847	-0.70288	0.43621	-0.479	29	0.636	Accept H0
Pair 45	OYN5 - OYN8	0.50000	1.73702	0.31714	-0.14861	1.14861	1.577	29	0.126	Accept H0
Pair 46	OYN5 - OYN9	1.50000	3.14862	0.57486	0.32429	2.67571	2.609	29	0.014	Reject H0
Pair 47	OYN5 - OYN10	1.00000	2.84059	0.51862	-0.06069	2.06069	1.928	29	0.064	Accept H0
Pair 48	OYN5 - OYN11	15.86667	4.81186	0.87852	14.06989	17.66345	18.061	29	0.000	Reject H0
Pair 49	OYN5 - OYN12	15.03333	5.14938	0.94014	13.11052	16.95614	15.990	29	0.000	Reject H0
Pair 50	OYN5 - OYN13	14.40000	5.63609	1.02900	12.29545	16.50455	13.994	29	0.000	Reject H0
Pair 51	OYN6 - OYN7	-0.43333	1.50134	0.27411	-0.99394	0.12728	-1.581	29	0.125	Accept H0
Pair 52	OYN6 - OYN8	0.20000	2.49689	0.45587	-0.73236	1.13236	0.439	29	0.664	Accept H0
Pair 53	OYN6 - OYN9	1.20000	3.61415	0.65985	-0.14955	2.54955	1.819	29	0.079	Accept H0
Pair 54	OYN6 - OYN10	0.70000	2.87858	0.52555	-0.37488	1.77488	1.332	29	0.193	Accept H0
Pair 55	OYN6 - OYN11	15.56667	4.94580	0.90298	13.71988	17.41346	17.239	29	0.000	Reject H0
Pair 56	OYN6 - OYN12	14.73333	5.00988	0.91467	12.86262	16.60405	16.108	29	0.000	Reject H0
Pair 57	OYN6 - OYN13	14.10000	5.13507	0.93753	12.18253	16.01747	15.039	29	0.000	Reject H0
Pair 58	OYN7 - OYN8	0.63333	2.41380	0.44070	-0.26799	1.53466	1.437	29	0.161	Accept H0
Pair 59	OYN7 - OYN9	1.63333	3.22152	0.58817	0.43040	2.83627	2.777	29	0.010	Reject H0

Table 1 continues on the next page →

TABLE 1 (Continues...): Comparative analysis of the inhibition zones produced by the different soap samples.

Pair	Sample codes	Mean	Std. deviation	Std. error mean	95% Confidence interval of the difference		*t*	df	Sig (2-tailed) $P < 0.05$	Decision
					Lower	Upper				
Pair 60	OYN7 - OYN10	1.13333	3.10432	0.56677	-0.02584	2.29250	2.000	29	0.055	Accept H0
Pair 61	OYN7 - OYN11	16.00000	4.86366	0.88798	14.18388	17.81612	18.018	29	0.000	Reject H0
Pair 62	OYN7 - OYN12	15.16667	5.01778	0.91612	13.29300	17.04034	16.555	29	0.000	Reject H0
Pair 63	OYN7 - OYN13	14.53333	5.55681	1.01453	12.45839	16.60828	14.325	29	0.000	Reject H0
Pair 64	OYN8 - OYN9	1.00000	2.50517	0.45738	0.06456	1.93544	2.186	29	0.037	Reject H0
Pair 65	OYN8 - OYN10	0.50000	1.73702	0.31714	-0.14861	1.14861	1.577	29	0.126	Accept H0
Pair 66	OYN8 - OYN11	15.36667	4.54467	0.82974	13.66966	17.06367	18.520	29	0.000	Reject H0
Pair 67	OYN8 - OYN12	14.53333	5.00161	0.91316	12.66570	16.40096	15.915	29	0.000	Reject H0
Pair 68	OYN8 - OYN13	13.90000	5.73164	1.04645	11.75977	16.04023	13.283	29	0.000	Reject H0
Pair 69	OYN9 - OYN10	-0.50000	2.51547	0.45926	-1.43929	0.43929	-1.089	29	0.285	Accept H0
Pair 70	OYN9 - OYN11	14.36667	5.18940	0.94745	12.42891	16.30442	15.163	29	0.000	Reject H0
Pair 71	OYN9 - OYN12	13.53333	5.52570	1.00885	11.47000	15.59666	13.415	29	0.000	Reject H0
Pair72	OYN9 - OYN13	12.90000	6.11019	1.11556	10.61842	15.18158	11.564	29	0.000	Reject H0
Pair 73	OYN10 - OYN11	14.86667	4.55414	0.83147	13.16612	16.56721	17.880	29	0.000	Reject H0
Pair 74	OYN10 - OYN12	14.03333	5.16943	0.94380	12.10304	15.96363	14.869	29	0.000	Reject H0
Pair 75	OYN10 - OYN13	13.40000	5.88745	1.07490	11.20159	15.59841	12.466	29	0.000	Reject H0
Pair 76	OYN11 - OYN12	-0.83333	4.19428	0.76577	-2.39950	0.73284	-1.088	29	0.285	Accept H0
Pair 77	OYN11 - OYN13	-1.46667	5.41857	0.98929	-3.48999	0.55666	-1.483	29	0.149	Accept H0
Pair 78	OYN12 - OYN13	-0.63333	3.29559	0.60169	-1.86393	0.59726	-1.053	29	0.301	Accept H0

H0, there are no significant differences in the antibacterial activities of the different soaps ($p < 0.05$*);*
OYN1 – OYN10, Different black soap samples; OYN11 – OYN13, Different medicated antibacterial soaps; *t, t-test;* df, degree of freedom.

black soap in some parts of Africa, has been in practice indigenously. Today, the number of plant materials being used, either alone or in combinations, in ethnomedicine is in the hundreds, and the new discoveries are becoming more and more exotic of each day, at the expense of the medicinal potential invested in African black soap. Mere handling of African black soap by some people is considered a taboo because of its use by the traditional healers, civilisation and modernisation, whereas a skin infection that could have been healed by using cheap and effective African black soap with great medicinal potential is allowed to aggravate and become a chronic, contagious and long-term infection.

In this study, the medicinal potential of African black soap with respect to its advantage over some commonly sold antibacterial medicated soap is elucidated. All the black soaps exhibited varied degrees of inhibitory effects against the growth of different bacterial strains. It revealed that the antibacterial effect of African black soap on *S. aureus*, *E. coli, P. aeruginosa, K. pneumoniae* and *E. faecalis* was significantly higher ($p > 0.05$) than those of the antibacterial medicated soaps. Although their antibacterial effects were concentration dependent and effective at very low MICs ranging between 0.125 mg/mL and 4 mg/mL, those of the medicated soaps were significantly higher. The susceptibilities of these organisms to the different black soaps indicated their therapeutic potentials in the treatment of wound and skin infection in which they might be involved and justified their use in ethnomedical practices.

Although this study is in agreement with the report of Popoola (2005), their antibacterial activities compared with those of antibacterial medicated soap are rare. Although the active ingredients in medicated soap are known and are often rich in glycerine, detergents, isopropylalcohol and some chemicals capable of causing irritation on dry and sensitive skin types (Omobuwajo et al. 2011), the antibacterial potential of African black soap may be attributed to the synergy between the phytochemicals in the plants and oils serving as components of the black soaps. These phytochemicals may include bioactive compounds such as alkaloids, flavonoids, pigments, phenolics, terpenoids, steroids and essential oils (Rajeshkumar et al. 2002). The palm kernel oil contains dodecanoic acid (Collin & Hilditch 1928), whereas the palm oil contains saturated palmitic, oleic and linoleic acid (Duke 1983). The shea butter is composed of five principal fatty acids, palmitic, stearic, oleic, linoleic and arachidic acid, with stearic and oleic acids accounting for 85% – 90% of its fatty acid (Maranz et al. 2004). Although the fatty acids and their derivatives in the oil used can have adverse effects on different bacteria (Kabara 1978) and act as anionic surfactants, targeting the structure and function of bacterial cell wall and membranes, with antibacterial activity at low pH (Hayes & Berkovitz 1979), fatty acids such as stearic and palmitic acid and hydroxyl fatty esters such as hydroxyl esters of stearic, plamitic and myristic acids also possess antibacterial properties (Bhattacharya et al. 2007; Liao et al. 1999). Although palm kernel oil has phenolic compounds known to have antimicrobial activities (Steven et al. 2003), its lauric acid has also been considered to have antibacterial properties (Ugbogu 2006). These soaps, to a large extent, remove dirt and disrupt cytoplasmic membrane to kill microorganisms (Tachibana 1976) and inhibit fatty acid synthesis by binding to bacterial enoyl-acyl carrier protein reductase enzyme (McMurry et al. 1998). Although the long chain fatty acids may have disrupted bacterial membrane integrity leading to leakage of macromolecules such as

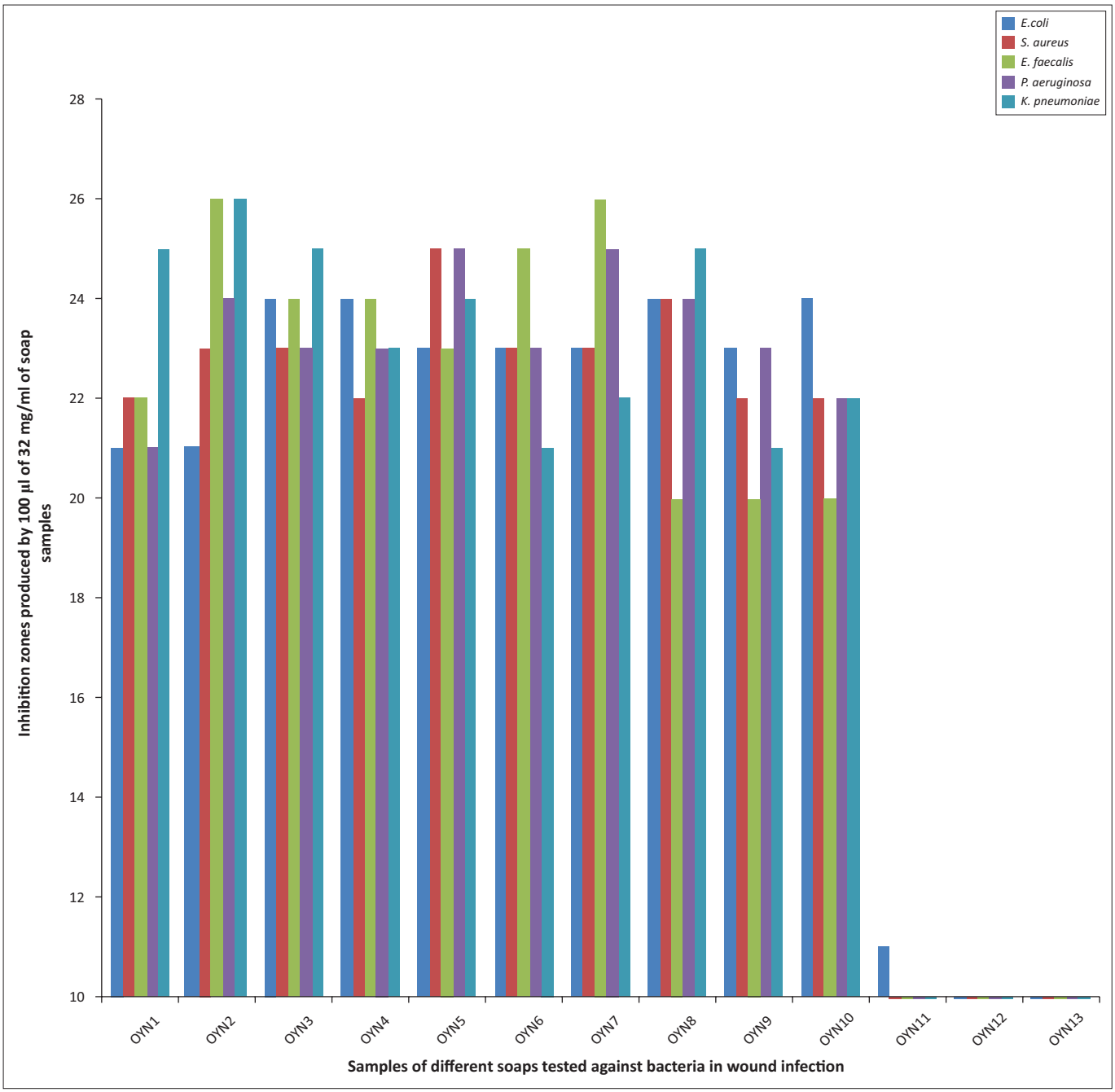

FIGURE 1: Susceptibility of bacterial isolates to 100 µL of 32 mg/mL of different soap samples.

nucleotide, inorganic acids or phosphorylated ammonium compounds (Arora 2010), Desbois and Smith (2010) reported that free fatty acids are capable of inhibiting the bacterial electron transport chain, oxidative phosphorylation, enzyme activity, impairment of nutrient uptake, generation of peroxidation and auto-oxidation degradation products or direct lysis of bacterial cells. Hence, the antibacterial activity of the African black soaps may have been because of the proportion of the fatty acid portions and the phytoconstituents in the plants used.

Considering the materials required in its production, it may be concluded that the production of African black soap is, simply, a conversion of waste to wealth. The black soap is made from the ashes of plantain skin, cocoa pod, palm leaves and palm oil from kernels. Harvesting these wastes for massive production of black soap would be of economic significance. Eroding the notion that the use of black soap is fetish would promote the image, and its general acceptability will put the soap in high demand. This would bring about economic turn-around in the parts of Africa where it is being produced. Improving its packaging and the addition of pharmaceuticals relevant in cosmetic pharmacy will, also, put the African black soap on high marketable pedestals with medicated soaps globally accepted. Black soap is a monumental economic product from waste materials which must be tapped for global economic development especially in Africa.

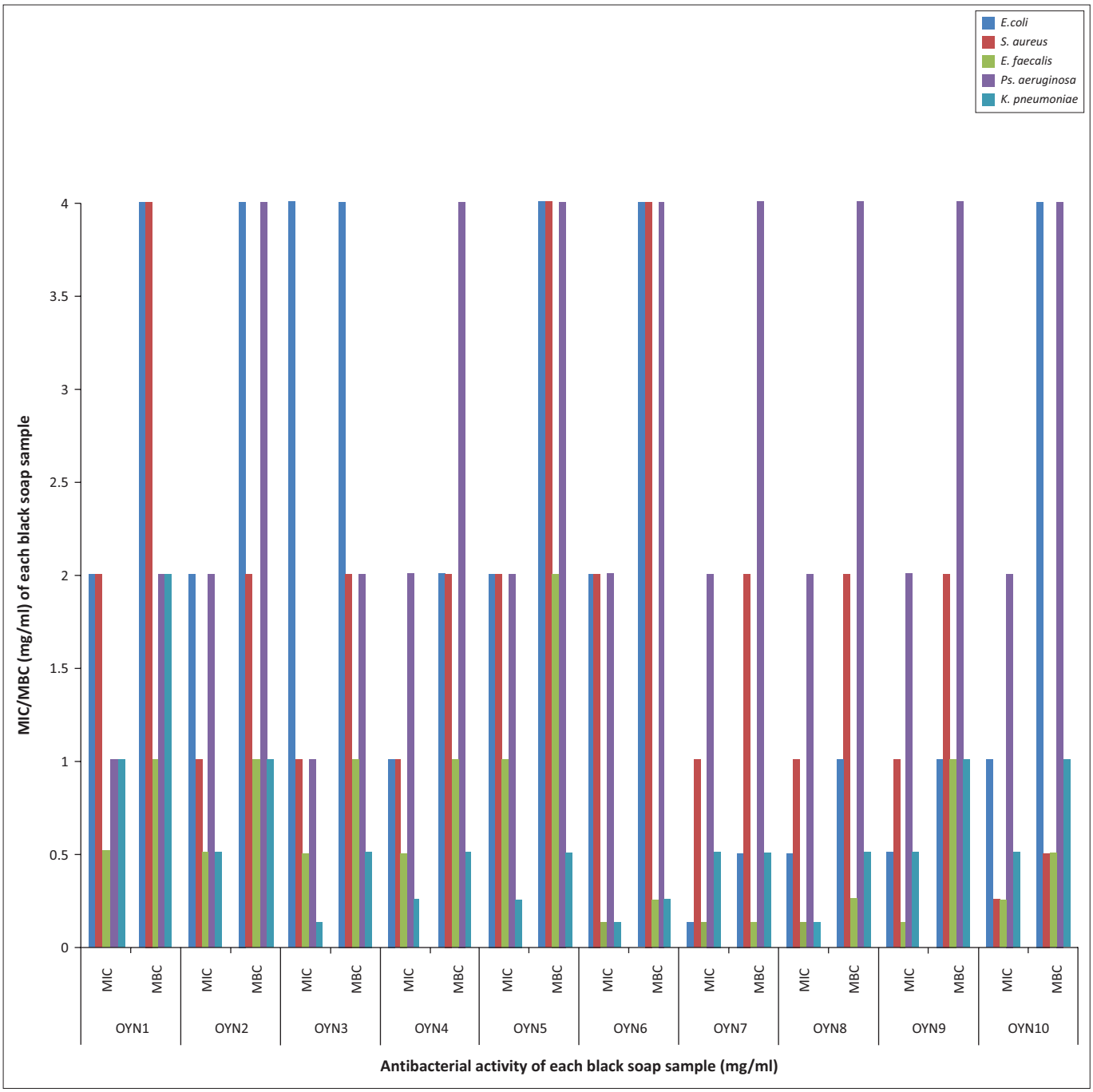

FIGURE 2: Composite bar chart showing the minimum inhibitory concentration and minimum bactericidal concentration of the different African black soaps.

In conclusion, because antibacterial activity is the ability to either destroy bacteria or inhibit their growth and soaps have been known to play important roles in killing bacteria and treating dermatitis and psoriasis, the African black soaps in this study showed significant antibacterial activity greater than those of the medicated soaps and justified their ethnomedicinal use in the treatment of skin infections. The study, therefore, signifies the ethnomedicinal importance of African black soaps as having a great potential in restraining the growth of multidrug resistant infectious microorganisms and can be a better option in place of commercially available antibacterial medicated and antiseptic soaps. Its cost of production is low compared to the amount of wealth that could be generated if it is globally accepted.

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Competing interests

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

Authors' contributions

All authors contributed equally to the conception, generation of data, data analysis and writing up and agreed together to the submission of the manuscript to this journal.

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