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Chemical Constituents and Antimicrobial Evaluation of Selected *Aloe vera* Branded Commercial Products in Tanzania

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Abstract

Chemical compositions and antimicrobial activities of twenty-two *Aloe vera* branded commercial products in Tanzania, a case of marketed soaps, creams, lotions, petroleum jelly, toothpastes and hair conditioner products in Dar es Salaam, were investigated. Chemical compositions were analysed using gas chromatography-mass spectrometry (GC-MS) whereas antimicrobial activities were evaluated using agar dilution method against four bacteria species, namely *Staphylococcus aureus, Escherichia coli, Klebsiella pneumoneae* and *Salmonella typhi*) and two fungal species *Candida albicans* and *Cryptococcus neoformans*. The GC-MS analysis revealed the presence of seven non-polar constituents, namely methyl palmitate, 9-octadecenoic acid methyl ester, methyl stearate, tetratetracontane, hexacosane, and pentacosane and methyl tetradecanoate as the most common ingredients among the products. Eleven compounds were detected in both the commercial products and reference *A. vera* extracts. The commercial products AVC5 and AVL3 inhibited the growth of *E. coli* and *S. typhi* at minimum inhibitory concentrations (MICs) of 7.5 and 12.5% (v/v), respectively, whereas AVC2 and AVC5 inhibited the growth of *C. albicans* and *C. neoformans* at 5.0% (v/v). AVC6 had 7.5 and 15.0% (v/v) MICs for *C. neoformans* and *C. albicans*, respectively. Other commercial products and the reference *A. vera* extracts were inactive against the tested microbes at a screening concentration of 10.0 mg/mL.

Keywords: *Aloe vera*; *Aloe vera* branded commercial products; GC-MS; Antimicrobial.

Introduction

Human beauty and health are as old as ancient civilization and have remained to be of imperative concern since then to contemporary world (Cock 2015, Maan et al. 2018, Kumar et al. 2019). The most important trend in the modern world health and beauty industry is the return to applications of products composed of herbal ingredients (Chattaraj et al. 2018). Although many plant extracts are included in the formulations of various commercial products commonly sold in the world markets, *Aloe* species ingredients take the large proportion with *A. vera* being the most spanning (Pandey and Singh 2016, Maan et al. 2018, Kumar et al. 2019). Since ancient civilization, the use of products containing *A. vera* extracts in foods, drinks, cosmetics and pharmaceuticals, and their outcomes on improving human health and appearance have been well documented (Maan et al. 2018, Kumar et al. 2019). Hence, *Aloe* extracts are used for nutritious drinks, as moisturizers, curing agents in cosmetics and over-the-counter medicines. The use of *Aloe* species in modern medicine and cosmetics is attributed to their varying phytochemical contents as a

result of interspecies variations, varying climate and soil conditions (Cousins and Witkowski 2012, Radha and Laxmipriya 2015, Jadhav et al. 2020, Bunea et al. 2020).

Despite the common use of *Aloe* species in cosmetics, food and pharmacological industry, some reports have indicated inefficiencies of the products for the intended purposes (Frisk 2016, Minjares-Fuentes et al. 2018). Evidence exist that some *Aloe* branded commercial products contain very little *Aloe* ingredients, while others had no expected *Aloe* constituents at all as acclaimed on the labels (Frisk 2016). Adulteration is therefore a major concern for commercial *Aloe* products in the market (Bozzi et al. 2007, Frisk 2016). It appears that manufacturers gain profits by adding adulterants and selling the products branded *A. vera*. Therefore, the composition and bioactivities of various kinds of *A. vera* branded commodities marketed in Dar es Salaam Tanzania and probably elsewhere might be exaggerated as some may lack substantial amounts of *Aloe* ingredients. Thus, this study was prompted by the plethora of *A. vera* branded products marketed in Dar es Salaam Tanzania that have not been validated for their constituents and antimicrobial activities. In this investigation, the *A. vera* branded products (mainly cosmetics) were selected randomly from various shops in Dar es Salaam to validate the presence of ingredients of *A. vera* and their potential or acclaimed antimicrobial activities.

Materials and Methods

Collection of *Aloe vera* branded commercial products

Twenty-two different types of *A. vera* branded commercial products were collected in January 2018 from shops around Kariakoo Market area in Dar es Salaam, Tanzania. The sampling involved both local and imported products which included soaps (AVS), creams (AVC), lotions (AVL), toothpastes (ATP), hair conditioners (AVH), Jellies (AVJ), facial make-ups (AVLp and AVMkp). These are coded and categorized as shown in Table 1. While AVS2, AVS4, AVS5, AVC2, AVC5, AVC6, ATP, AVH1, AVJ1 and AVMkp are imported products, the rest are manufactured by both large and small local industries registered in Tanzania.

Table 1: Investigated *Aloe vera* commercial products

Sample code	Product type	Sample code	Product type
AVS1	Soaps (AVS)	AVL1	Lotions (AVL)
AVS2		AVL2	
AVS3		AVL3	
AVS4		ATP	Toothpaste (ATP)
AVS5		AVH1	Hair conditioners (AVH)
AVS6		AVH2	
AVC1	Creams (AVC)	AVJ1	Petroleum Jelly (AVJ)
AVC2		AVJ2	
AVC3		AVLp	Lipstick (AVLp)
AVC4		AVMkp	Make-up (AVMkp)
AVC5			
AVC6			

Reference plant materials collection

Fresh leaves of *Aloe vera* used to prepare reference *A. vera* extracts were collected in March 2018 from Kilimanjaro *Aloe* plantation farm, at Kikuletwa Village, Moshi District in Kilimanjaro Region, Tanzania. The *A. vera* species cultivated in that farm is for commercial purposes. The plant species was identified in the field and confirmed at the Herbarium of the Botany Department, University of Dar es Salaam where voucher specimen FMM 3499 is deposited.

Chemicals, solvents and other materials used

All the chemicals and reagents used in the investigations were of analytical grade, purchased from chemical suppliers. The

chemicals included dimethyl sulfoxide (DMSO, b.p. 189 °C), potassium hydroxide, sodium hydroxide, sulfuric acid, toluene and sodium sulfate. Solvents used in the study were methanol (b.p. 64.6 °C, Merck KGaA, CAS No. 67-56-1), dichloromethane (b.p. 36.6 °C, Leo Chem India, CAS No. 75-09-2), petroleum ether (b.p. 40-60 °C, Leo Chem India, CAS No. 64742-82-1) and ethyl acetate (b.p. 77.1 °C, Merck KGaA, CAS No. 141-78-6). Tryptic Soya Agar (TSA) and Sabraoud Dextrose Agar (SDA) produced by Liofilchem srl, Zona ind.le-Roseto d. Abruzzi (TE)- Italy were used as media for bacterial and fungal growth, respectively. The standard drugs Clotrimazole and Gentamicin were used as reference compounds for inhibition of fungal and bacterial growth, respectively.

Preparation of the sample solutions and extracts

Twenty-two *A. vera* branded commercial products were analysed. The sample solutions were prepared by dissolving 3 g of the sample in methanol, dichloromethane or petroleum ether or in a mixture of two of these solvents in order to ensure the samples are completely dissolved. The fresh leaves of *A. vera* were washed thoroughly with tap water and then rinsed with distilled water. The saw-toothed edges of the leaves were cut, followed by peeling of the two sides of the green portion of the leaves. The clear soft gel and the latex obtained were then transferred to separate clean beakers. 500 g of *Aloe* leaf gel and leaf latex were separately homogenized using mortar and pestle, and extracted twice successively using petroleum ether, dichloromethane and methanol for 48 hours. Water was removed by liquid-liquid partitioning using ethyl acetate on a separating funnel. The organic phase was left at room temperature for solvent to evaporate then stored in refrigerator at 4 °C until required for GC-MS analysis and bioassays.

Methylation of the samples for GC-MS analysis

In a clean beaker, 1 g of sample was weighed, followed by addition of 10 mL of toluene and 10 mL of 10% sulfuric acid in methanol. The mixture was then shaken and kept in a water bath for 16 h at 50 °C. On cooling to room temperature, 10 mL of water and NaOH were added. This was then transferred into a separating funnel followed by addition of 10 mL dichloromethane, thoroughly shaken and left to settle for 2 h. The organic layer was tapped, then dried by adding 1 g of Na_2SO_4. The dehydrated organic layer was filtered, then transferred to vials for GC-MS analysis. The same procedure was done for *A. vera* extracts.

Chemical composition analysis

The chemical composition of *A. vera* commercial products and reference *A. vera* extracts were established by GC-MS performed on QP 2010 Shimadzu (Japan), with an AOC-20i/s auto-sampler. The instrument was operated in Electron Ionization (EI) mode at 70 eV and Flame Ionization Detector (FID) for GC. The GC separation was performed with Restek-5MS column (30 m x 0.25 mm x 0.25 µm) with the oven temperature program ranging from 110 to 280 °C whereby it was held at 110 °C for two minutes, then steadily increased to 280 ^{o}C within 34 min at a rate of 5 °C per minute. The samples were dissolved in a mixture of methanol and acetone (1:1) to give a solution that was injected into GC-MS. The injection temperature was 250 °C with splitless injector mode. The carrier gas was helium (99.99%) with the flow rate of 2.14 mL/min. The ion source temperature and interface temperature in the MS were 280 °C and 300 °C, respectively. The identification of compounds in the sample was done by scan method, which involves the use of Mass Spectral Library and Search Software (National Institute of Standards and Technology, NIST). The quantification was done using peak integration method, where by ion allowance was 20%, target ion and other four reference ions were used. The results are reported as percentage composition using peak height.

Preparation of the samples for antimicrobial assays

For the liquid products, 0.5 to 3 mL (Table 2) were directly used after maintaining them in a water bath of 40-45 °C for five minutes. The solid and semi-solid products such as soaps, creams and toothpastes (300 mg of each product) were weighed then dissolved in 30 mL of distilled water to make the highest concentration of 10 mg/mL. From this solution, specific volumes were drawn and mixed with agar, resulting into different concentrations (v/v%) of the *A. vera* commercial products as given in Table 2.

Table 2: Agar and *Aloe vera* commercial products solution mixing volumes

Experiment	1	2	3	4	5	6
Amount of *Aloe vera* product measured (mL)	0.5	1.0	1.5	2.0	2.5	3.0
Volume of media/Agar measured (mL)	19.5	19.0	18.5	18.0	17.5	17.0
Volume of mixture (mL)	20.0	20.0	20.0	20.0	20.0	20.0
% Concentration (v/v) of mixture (serial dilution)	2.5	5.0	7.5	10.0	12.5	15.0

Preparation of bacterial and fungal inocula

By using a sterile wire loop, colonies of the test bacteria and fungi from sub-cultured plate were separately emulsified into vial containing sterile distilled water to make a suspension equivalent to McFarland 0.5 turbidity. The inoculum was prepared after every three days in order to overcome the effect of over growth.

Antimicrobial assays by determination of minimum inhibition concentration

The studied products were evaluated for antimicrobial activities against two fungal species, *Candida albicans* (ATCC 90028) and *Cryptococcus neoformans* (Clinical isolate), a Gram-positive bacterium *Staphylococcus aureus* (ATCC 25923) and three Gram-negative bacteria *Salmonella typhi* (ATCC 19430), *Klebsiella pneumoneae* (ATCC 708903) and *Escherichia coli* (ATCC 25922). The antimicrobial activities were evaluated by the agar dilution assay (Osés et al. 2016). The dilution involved the use of freshly prepared and autoclaved agar (TSA and SDA for bacteria and fungi, respectively) that was allowed to cool in water bath at 45-50 °C before use. The warm agar and *A. vera* commercial products solution of different volume were measured, mixed and then vortexed making a final volume of 20 mL in a sterilized labelled petri dish and left for three hours to solidify. The concentrations in the plates were 15% [3 mL of *A. vera* commercial products solution in 17 mL of agar, volume/volume (v/v)], 12.5% (v/v), 10.0% (v/v), 7.5% (v/v), 5.0% (v/v) and 2.5% (v/v). The plates were inoculated aseptically with the test organisms by streaking using sterile cotton swab, then incubated for 24 hours. A negative control plate without antimicrobial agent was also prepared for every test organism. MIC was the lowest concentration of *A. vera* commercial product that inhibited the growth of microbes determined by visual inspection or by applying a dye (*p*-iodonitrotetrazolium violet, INT). The same procedures for the evaluation of the antimicrobial activities were also carried out for the reference *A. vera* species extracts and the standard antibacterial and antifungal drugs. The extract and standard drug solutions were prepared by dissolving 10.0 mg and 1.0 mg into 1.0 mL of DMSO, respectively.

Quality control and assurance

The quality and accuracy of the analytical results were monitored by analysing each sample in triplicate, along with appropriate reference materials and control experiments. Analytical grade chemicals and distilled water were used for the sample preparation and analysis. In order to monitor contamination, the solvent blanks were analysed in parallel with all the samples analysed by GC-MS. Plant materials were subjected to two consecutive extractions to ensure high extraction efficiency. To ensure high solubility, appropriate solvent systems were used. After all the samples were

dissolved, the resulting solutions were stored at 4 °C in the refrigerator to prevent evaporative losses and possible degradation.

Results and Discussion

Chemical composition analysis

Chemical composition of *Aloe vera* branded soap solutions

The GC-MS analysis of six solutions of *Aloe vera* branded commercial soaps revealed the presence of 10, 8, 7 and 6 components in AVS3, AVS5, AVS6 and AVS2, respectively (Table 3). On the other hand, AVS1 and AVS4 had 5 components each (Table 3). The soap solutions indicated three common constituents that included methyl palmitate, methyl tetradecanoate and methyl stearate as the major components. Methyl palmitate was the highest in AVS1 (67.8%). Moreover, relative compositions of methyl stearate were found to be 29.3% in AVS5, 27.8% in AVS6, 18.9% in AVS2 and 18.6% in AVS3. AVS2 indicated the highest composition of methyl tetradecanoate in comparison to the other analysed *A. vera* branded commercial soaps. Furthermore, the soap product revealed two more compounds, namely dodecanoic acid methyl ester and 9-octadecenoic acid methyl ester (*E*) that were similar in the four soap samples (Table 3). Few components including methyl palmitate and methyl linoleate identified from the *A. vera* branded soap products were also found in the *A. vera* extracts (Table 4).

Chemical composition of *Aloe vera* branded cream solutions

The GC-MS analysis of the *A. vera* commercial cream solutions revealed the presence of seven compounds in AVC4, five compounds in AVC2 and AVC3, four compounds in AVC1, AVC5 and AVC6. The ingredients such as glycerin (92.4%), methyl palmitate (49.0%), *n*-nonadecanol- 1 (48.5%), behenic alcohol (48.1%), 1-pentadecanamine, *N,N*-dimethyl- (47.6%), 1-tetradecanol (45.9%) and methyl stearate (39.0%) were the main components of the cream solutions (Table 3). The ingredients showed variations in compositions among the cream products. However, most of the ingredients identified from the cream solutions were fatty alcohols and acids. The ingredients such as methyl palmate, methyl stearate, glycerin and methyl paraben were among the expected compounds from the products as they were declared by the manufactures and are known to be present in most creams. Despite their estrogenic effects, parabens such as methylparaben and propylparaben are commonly used in cosmetics as preservative agents (Nowak et al. 2018). Some of the components identified from the cream products were also identified from the reference *A. vera* species extracts. These include among others, methyl palmitate and *n*-hexadecanoic (Table 4). Therefore, identifying them from the *A. vera* branded products may cautionary be assumed that they are of *Aloe* origin. Such compounds have also been identified along with octadecanoic acid methyl ester and methyl linoleate in other plant species such as *Cenchrus ciliaris* (Arora et al. 2017).

Chemical composition of the *Aloe vera* lotion solutions

The GC-MS analysis revealed the presence of twelve components in both AVL1 and AVL2 whereas five components were identified in AVL3 as depicted in Table 3. The lotion solutions had three major components, namely, methyl 18-methylnonadecanoate, tetratetracontane and isopropyl myristate. Five constituents from *A. vera* lotion solutions were also identified in *A. vera* extracts. These included methyl palmitate, *n*-nonadecanol, pentatriacontane, *n*-hexadecanoic acid and tetratetracontane (Table 4). *n*-Hexadecanoic acid and tetratetracontane were found in AVL1 and AVL3, respectively. Three compounds, namely methyl palmitate, *n*-nonadecanol and pentatriacontane were found in AVL2. Generally, the percentage compositions of the ingredients from the *A. vera* lotions were low compared to those identified in the *A. vera* soap solutions (Table 3).

Chemical composition of the *Aloe vera* hair conditioner solutions

The GC-MS analysis of *A. vera* branded hair conditioner solutions revealed the presence of ethanol, 2-(dodecyloxy)- (18.2%), diethylene glycol monododecyl ether (14.8%), 2-methyl dodecan-1-ol (*S*)- (13.1%), dodecylheptaglycol (10.9%), ethanol, 2-(tetradecyloxy)- (10.2%) and 1-hexadecanol (9.1%) in AVH2 and hexacosane (14.7%), heptacosane (14.3%), octacosane (13.9%), nonacosane (11.9%) and tetratetracontane (9.3%) in AVH1 as the major components (Table 3). The components from hair conditioner solutions that were also identified in *A. vera* extracts included tetratetracontane, pentatriacontane and hentriacontane (Table 4).

Chemical composition of the *Aloe vera* jelly solutions

The GC-MS analysis of the jelly solutions indicated them to contain large proportions of lipid hydrocarbons in both AVJ1 and AVJ2. Thus, the chemical profiling of the solutions revealed the presence of 13.9% and 13.3% octacosane, 13.7% and 12.6% hexatriacontane, 11.7% and 9.0% tetracontane, 11.5% and 9.8% hexacosane, and 7.6% and 7.2% pentacosane as the major constituents in AVJ1 and AVJ2, respectively. Hentriacontane (14.2%), heptacosane (13.7%) and tritetracontane (6.8%) found in AVJ1 as well as 2-methyloctacosane (14.8%) and pentatriacontane (13.7%) in AVJ2 were the other main constituents of these products along with moderate compositions of tetratetracontane (5.6% and 4.2% in AVJ1 and AVJ2, respectively) and heneicosane (5.5% and 4.3% in AVJ1 and AVJ2, respectively) (Table 3). Seven ingredients from the jelly solutions were also identified in *A. vera* extracts (Table 4). These included tetratetracontane, pentacosane, hexatriacontane and tetracontane that were identified from both jelly solutions and *A. vera* extracts. Two additional ingredients, namely pentatriacontane and 2-methyloctacosane found in AVJ2 were also found in *A. vera* extracts inferring that the products' formulation contained *A. vera* constitutes.

Chemical composition of the *Aloe vera* lipstick solutions

Chemical analysis of *Aloe vera* lipstick solution revealed five compounds as indicated in Table 3 with their percentage compositions being 32.9, 30.8, 20.8, 11.4 and 4.1% for pentacosane, heneicosane, hentriacontane, tetratetracontane and hexadecanoic acid-octadecyl ester, respectively. Four of the constituents of *A. vera* lipsticks were also identified in the solutions of other *A. vera* commercial products. These constituents included hentriacontane, tetratetracontane, pentacosane and heneicosane (Table 3). Hentriacontane, tetratetracontane and pentacosane were also identified in *A. vera* extracts (Table 4). The *Aloe* lipsticks analysed were claimed to contain high concentrations of vitamin E on their labels. However, the compound was not detected in GC-MS, possibly due to its polarity. Inclusion of vitamin E in most lipsticks' products may be attributed to its antioxidant property (Maya et al. 2012).

Chemical composition of the *Aloe vera* facial powder cake solutions

GC-MS analysis of the AVMkp solution revealed the presence of five compounds that were mainly fatty acid methyl esters and hydrocarbons (Table 3), with methyl palmitate (52.2%) and methyl stearate (46.7%) being the major constituents. The constituents were also identified in other *A. vera* branded products such as AVS, AVC, AVL2, AVL3 and AVJ2 as well as the *A. vera* species extract (Tables 3 and 4). The constituents that occurred in minor quantities in the JPC solution were methyl isotetradecanoate (0.5%), 2-methyltetracosane (0.4%) and heptadecane (0.3%). Other constituents were neither identified in the other commercial products nor in the reference *A. vera* extracts. The product ingredients on the labels included kaolin, titanium dioxide, magnesium stearate, silicon oil, lanolin oil, mineral oil, methyl

paraben, propyl paraben, and fragrance. It should be noted that, of the indicated organic constituents, stearate was the only component identified matching with the manufacturers' declared ingredients. Stearate is among the common ingredients used in cosmetics due to its lubricating and emulsifying property.

Chemical composition of the *Aloe* toothpaste solutions

Two compounds identified in the *Aloe* toothpaste (ATP) solutions were isosorbide (92.2%) and dianhydromannitol (7.8%) with the former being a major component (Table 3). These components were neither detected in all the investigated *A. vera* branded commercial products nor from the reference *A. vera* species extracts, hence the likelihood that they do not originate from the *Aloe* species. While isosorbide and dianhydromannitol have neither been reported from *A. vera* nor other *Aloe* species, the former compound has been reported from *Lawsonia inermis* (Rajeswari and Rani 2015) whereas the latter has been reported from the same plant (*L. inermis*) and other plant species such as *Hugonia myristax* and *Carica papaya* (Rajeswari and Rani 2015, Ezekwe and Chikezie 2017). Isosorbide is also synthetically obtainable from catalytic hydrogenation of D-glucose or acid-catalyzed dehydration of D-sorbitol (Rose and Palkovits 2012). Industrially, it is synthesized from the renewable resources like sugar (Saxon et al. 2019). Its use in toothpastes and other cosmetics is derived from its humectant and surfactant properties (Le Guenic et al. 2019). However, in this particular product, neither the identified ingredients nor other constituents used in the formulations of toothpastes were declared on the labels.

Antimicrobial activities

Out of the twenty-two investigated products, only two (AVC5 and AVL3) were active against the four tested bacteria at 10 mg/mL, the screening concentration used. By employing the agar dilution method, AVC5 demonstrated antibacterial activities against *E. coli, K. pneumonia, S. aureus* and *S. typhi* with MIC of 7.5, 10.0, 12.5 and 15.0%, respectively. On the other hand, AVL3 had an MIC value of 12.5% against *S. typhi* and 15.0% for other bacterial species tested. Three products that demonstrated activity against the two fungal species tested were AVC2 and AVC5 with 5.0% MIC values against *C. albicans* and *C. neoformans* as well as AVC6 that was active against *C. neoformans* and *C. albicans* with MIC value of 7.5 and 15.0%, respectively. Among the ingredients present in these bioactive commercial products (for instance AVC3 and AVC5), methyl palmitate is reported to possess hypocholestrolemic, antimicrobial and antioxidant properties (Arora et al. 2017). Thus, the bioactivity observed for such products may be attributed to the incorporated *A. vera* extract components, other bioactive constituents in the products, or the synergistic effects of both.

Though most of the *A. vera* branded commercial products were expected to be active due to presence of *A. vera* constituents known for strong antimicrobial activities (Gupta and Kumar 2017, Kamble et al. 2013), this study did not establish significant activities. For instance, AVS1, AVS2 and AVS3, which were declared by the manufacturers to possess antibacterial activities, were found to be inactive against the tested bacteria. The observed inactivity for most of the *A. vera* branded commercial products could be due to the presence of small percentages of the *Aloe* extracts' constituents incorporated in the products, hence less effective concentrations. Although *A. vera* extracts have been reported to be antimicrobial agents elsewhere (Dharajiya et al. 2017, Saniasiaya et al. 2017), the reference *A. vera* species extracts used in the current study were also inactive to all the microbes tested at a screening concentration of 10 mg/mL. The low concentrations of the effective ingredients may have contributed to the observed inactivity. Studies by Kamble et al. (2013) and Dharajiya et al. (2017) ascertained that at higher concentrations, alcoholic extracts were more potent than petroleum ether and chloroform extracts tested against *E. coli*, *K. pneumoniae*, *S. aureus*, *A. niger* and *C. albicans*.

Table 3: Chemical compositions of the *Aloe vera* branded commercial products

Name of the compound	% Composition											
	AVS1	AVS2	AVS3	AVS4	AVS5	AVS6	AVC1	AVC2	AVC3	AVC4	AVC5	AVC6
Methyl palmitate	67.8	43.7	43.5	58.4	33.2	43.8	48.9	6.1	39.1	1.1	0.0	0.0
Methyl tetradecanoate	10.9	16.8	4.8	7.2	15.0	7.1	0.0	0.0	2.5	0.0	0.0	0.0
Methyl stearate	10.5	18.9	18.6	7.7	29.3	27.8	39.0	0.0	34.8	0.0	0.0	0.0
11-Octadecenoic acid, methyl ester	8.9	0.0	0.0	17.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dodecanoic acid, methyl ester	0.0	6.3	11.5	6.2	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9-Octadecenoic acid, methyl ester, (*E*)-	0.0	13.2	12.1	0.0	10.9	12.5	0.0	0.0	0.0	0.0	0.0	0.0
Decanoic acid, methyl ester	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9-Hexadecenoic acid, methyl ester, (Z)-	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxiraneoctanoic acid, 3-octyl-, methyl ester, *cis*-	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Glycerin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.4	0.0	0.0
n-Nonadecanol-1	0.0	0.0	0.0	0.0	0.0	0.0	8.3	48.5	14.5	0.0	0.0	0.0
Behenic alcohol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.1	0.0
1-Pentadecanamine, *N*,*N*-dimethyl-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.6
1-Tetradecanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.9	0.0	0.0	45.9	0.0
Hexadecanoic acid, hexadecyl ester	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.7
Pentatriacontane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5
2-Methylhexacosane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.2
Methylparaben	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.0	5.2	0.0
Methyl linoleate	1.7	0.0	6.8	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hexadecanoic acid, 15-methyl-, methyl ester	0.0	0.0	0.5	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Methyl 18-methylnonadecanoate	0.0	0.0	1.8	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0
Nonanoic acid, 9-oxo-, methyl ester	0.0	1.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0
Pentadecanoic acid, methyl ester	0.0	0.0	0.3	0.0	2.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0
1-Hexadecanol	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	9.2	0.0	0.0	0.0
Triacontanoic acid, methyl ester	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0	0.0	0.0
Dodecanoic acid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0
Tridecanoic acid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0
n-Hexadecanoic acid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
Octadecanoic acid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0
Heptadecyl trifluoroacetate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0

Table 3 (ctd): Chemical compositions of the *Aloe vera* branded commercial products

Name of the compound	% Composition									
	AVL1	AVL2	AVL3	AVH1	AVH2	AVJ1	AVJ2	AVLp	AVMkp	ATP
Methyl palmitate	0.0	28.3	27.0	0.0	0.0	0.0	5.9	0.0	52.2	0.0
Methyl tetradecanoate	28.5	0.0	0.0	16.7	0.0	0.0	0.0	0.0	0.0	0.0
Methyl stearate	0.0	18.3	0.0	0.0	0.0	0.0	0.0	0.0	46.7	0.0
n-Nonadecanol-1	0.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-Tetradecanol	0.0	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pentatriacontane	0.0	1.2	6.7	5.6	0.0	0.0	13.7	0.0	0.0	0.0
Hexadecanoic acid, 15-methyl-, methyl ester	12.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Methyl 18-methylnonadecanoate	21.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-Hexadecanol	0.0	0.0	0.0	0.0	9.1	0.0	0.0	0.0	0.0	0.0
n-Hexadecanoic acid	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetratetracontane	0.0	0.0	57.9	9.3	0.0	4.2	5.6	11.4	0.0	0.0
Isopropyl myristate	11.6	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0
Octacosane	0.0	3.0	0.0	14.0	0.0	13.9	13.3	0.0	0.0	0.0
Ethanol, 2-(dodecyloxy)-	0.0	0.0	0.0	0.0	18.2	0.0	0.0	0.0	0.0	0.0
Diethylene glycol monododecyl ether	0.0	0.0	0.0	0.0	14.8	0.0	0.0	0.0	0.0	0.0
2-Methyl dodecan-1-ol (S)-	0.0	0.0	0.0	0.0	13.0	0.0	0.0	0.0	0.0	0.0
Dodecylheptaglycol	9.6	0.0	0.0	0.0	10.9	0.0	0.0	0.0	0.0	0.0
Ethanol, 2-(tetradecyloxy)-	0.0	0.0	0.0	0.0	10.2	0.0	0.0	0.0	0.0	0.0
Hexacosane	0.0	1.8	0.0	14.7	0.0	11.5	9.8	0.0	0.0	0.0
Heptacosane	0.0	2.2	0.0	14.3	0.0	13.7	0.0	0.0	0.0	0.0
Nonacosane	0.0	3.3	0.0	11.9	0.0	0.0	0.0	0.0	0.0	0.0
Dodecanoic acid, undecyl ester	0.0	0.0	0.0	0.0	8.5	0.0	0.0	0.0	0.0	0.0
Triethylene glycol monododecyl ether	0.0	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0	0.0
n-Pentadecanol	0.0	0.0	0.0	0.0	5.5	0.0	0.0	0.0	0.0	0.0
Hentriacontane	0.0	3.2	0.0	8.5	0.0	14.2	0.0	20.8	0.0	0.0
1-Hentetracontanol	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0
Hexatriacontane	0.0	0.0	0.0	0.0	0.0	12.6	13.7	0.0	0.0	0.0
Tetracontane	0.0	0.0	0.0	0.0	0.0	9.9	11.7	0.0	0.0	0.0
Pentacosane	0.0	0.0	0.0	0.0	0.0	7.6	7.2	32.9	0.0	0.0
Tritetracontane	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2-Methyloctacosane	0.0	0.0	0.0	0.0	0.0	0.0	14.8	0.0	0.0	0.0
Heneicosane	0.0	0.0	0.0	0.0	0.0	5.5	4.3	30.8	0.0	0.0
Hexadecanoic acid, octadecyl ester	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.0
Tridecanoic acid, 12-methyl-, methyl ester	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
2-Methyltetracosane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Heptadecane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Cinnamaldehyde, alpha. -pentyl-	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-Octadecene	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hexadecane	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Octanal, 2-(phenyl methylene)-	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9-Octadecenoic acid (*Z*)-, methyl ester	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-Heneicosanol	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Name of the compound	% Composition									
	AVL1	AVL2	AVL3	AVH1	AVH2	AVJ1	AVJ2	AVLp	AVMkp	ATP
Isopropyl palmitate	0.0	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dotriacontane	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetrapentacontane, 1,54-dibromo-	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
n-Decanoic acid	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0
1-Octanol, 2-butyl-	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0
Heneicosanoic acid, methyl ester	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
Erucic acid	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
Tritetracontane	0.0	0.0	0.0	0.0	0.0	6.8	0.0	0.0	0.0	0.0
Isosorbide	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.2
Dianhydromannitol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8

Table 4: Chemical compositions of the reference *Aloe vera* leaf gel and leaf latex extracts

Name of the compound	% Composition		Name of the compound	% Composition	
	Leaf gel	Leaf latex		Leaf gel	Leaf latex
Petroleum ether extract			*Methanol extract*		
n-Hexadecanoic acid	0.4	2.2	Phytol	0.0	3.8
Pentacosane	0.0	81.7	Methyl linoleate	0.7	0.0
Lupenyl acetate	0.0	1.3	Methyl palmitate	2.6	0.0
Tetratetracontane	3.2	0.0	1-Octadecene	1.2	0.0
Hexatriacontane	4.8	0.0	Octacosanol	0.7	0.0
Hentriacontane	4.0	0.0	1-Tricosene	1.0	0.0
Pentatriacontane	4.8	0.0	1-Pentadecene	0.6	0.0
Tetracontane	4.6	0.0	Methyl cinnamate	0.0	22.5
9,12-Octadecadienoic acid (*Z, Z*)	0.9	0.0			
2-Methyloctacosane	2.6	0.0			
Dichloromethane extract					
Pentacosane	0.0	53.0	3,7,11-trimethyldodecan-1-ol	2.1	0.0
2',4'-Dihydroxy-3'-methylacetophenone	0.0	7.2	*n*-Nonadecanol-1	1.3	0.0
Hexadecanal	8.8	0.0	*cis*-9-Hexadecenal	1.0	0.0
cis, cis, cis-7,10,13-Hexadecatrienal	2.4	0.0			

Conclusion

The study analysed the chemical compositions and antimicrobial activities of twenty-two *A. vera* branded commercial products marketed in Dar es salaam, Tanzania in comparison to the ingredients from *A. vera* extracts used as reference. Most of the products were found to possess a number of common non-polar chemical constituents among themselves and in comparison with the *A. vera* extracts. Possession of similar compounds by most of the commercial products as compared to *A. vera* extracts, is indicative of the presence of the acclaimed *A. vera* ingredients in the products. The antimicrobial activities portrayed by some products support their use against some infectious microbes. However, the chemical constituents described in this study represent the non-polar components of the investigated products and *A. vera* extracts constituting fatty acids as the main constituents along with fatty alcohols, hydrocarbons, aldehydes, amines and furan. Therefore, analyses of polar components using HPLC and LC-MS are recommended for further validation.

Declaration of Competing Interest

The authors declare that there are no competing interests in relation to this work.

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