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Plants of Commercial Importance in Lesotho: Ethnobotanical and Pharmacological Insights

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Abstract: Several plants have been processed in Lesotho to manufacture various commercial prodcts, ranging from cosmetics and beverages (juice, tea) to traditional herbal mixtures and crafts. Even though plants of commercial importance have been documented in different regions and countries, this is not the case in Lesotho. Therefore, the aim of the study is to record plant species commonly used in the country for development of commercial products. A physical survey was undertaken in different places in the Maseru District of Lesotho between January 2019 and October 2021, taking a record of existing commercial products and identifying plants used in their development. A total of 15 plants of commercial importance in the country are recorded in the current study, namely *Agave americana*, *Aloe ferox*, *Artemisia afra*, *Cannabis sativa*, *Helichrysum odoratissimum*, *Hemannia depressa*, *Hypoxis hemerocallidea*, *Leudeboria cooperi*, *Mentha* spp., *Merxmuellera* spp., *Pelargonium sidoides*, *Opuntia ficus-indica*, *Rosa rubiginosa* and *Urtica urens*. Most of the plants are used for production of commercial products in the country, whereas some are exported as raw materials, mainly to countries such as Germany, South Africa, Australia and America. The latter are *C. sativa*, *Merxmuellera* spp., *P. sidoides* and *R. rubiginosa*. Profiling of the plants provides important information about their commercial potential. However, conservation of the plants is encouraged to ensure their sustainable utilisation.

Keywords: commercial products; crafts; herbal teas; medicinal plants; traditional herbal mixtures

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1. Introduction

Africa is endowed with a wide range of indigenous plants that play a major role in sustaining livelihoods of different communities [1]. Some of these plants are used in traditional medicine, cosmetics, flavourants and for ornamental purposes, whereas a small portion is used in the food and pharmaceutical industries [1]. The market for natural resource-based products is increasing, following the screening of plants, with the aim of discovering new natural compounds that could be of value in developing products for the food, cosmetics and pharmaceutical sectors [2]. It was predicted that the entire herbal product market would continue to steadily increase, reaching more than USD115 billion worldwide by the year 2020. The Asia–Pacific region is regarded as the most advanced market, whereas European countries are the largest growing market [2]. Indeed, several medicinal plants have been identified and tested to date for their pharmaceutical importance. Some of these plants have been found to be effective but very few of them have been commercialised to date. A diverse range of indigenous plants exists in Africa, creating a potential for commercialisation. Consequently, the continent has established several initiatives in research on plants that can be exploited for commercialisation [1]. Plants of commercial importance have been documented in various countries and regions, even

though a majority of these studies focused more on plants used for medicinal products. A total of 5400 commercially important African plants have been documented by [3], 10% of which have been commercially developed in Africa and entered international trade. A total of 175 of these plants are reported as the most popular and important medicinal plants of sub-Saharan Africa. Some of these species occur in Lesotho, and they include *Artemisa afra* Jacq. ex Willd, *Helichrysum odoratissimum* (L.) Sweet, *Hypoxis hemerocallidea* Fisch. & C.A. Mey., *Olea europaea* L. subsp. *africana* (Mill) P.S. Green., *Pelargonium sidoides* DC., *Withannia somnifera* (L.) Dunal and *Xysmalobium undulatum* (L.) Aiton f. African countries reported to have medicinal plants of commercial potential include Cameroon, Côte d'Ívoire, Swaziland (now Eswatini), Malawi, Nigeria, South Africa and Zimbabwe [1]. Consequently, successful business ventures have been developed from the use of indigenous plants, particularly in the medicinal industry in South Africa [1].

Lesotho is also rich in indigenous flora, with a total of 2096 species representing 674 genera and 172 families recorded [4]. A comprehensive review of the ethnobotany of a majority of these plants was provided by [5], which yielded 712 species comprising 22 pteridophytes and 690 flowering plants, being used for a variety of purposes such as food, fodder, medicine, clothing, crafts, furniture, building, musical instruments and magic. Some of these plants are sold as raw material locally in the informal markets of major towns such as Maseru and Maputsoe [6,7]. These include *Dicoma anomala* Sond. subsp. *anomala*, *Alepidea amatymbica* Eckl. & Zeyh., *Hypoxis hemerocallidea*, and *Pentanisia prunelloides* Klotzsch ex. Eckl. & Zeyh. Indeed, [6] reported that medicinal plants are no longer used for subsistence healing purposes but have been turned into products for trade in the traditional medicine markets in Lesotho. This study revealed that 40% of medicinal plants traded in these markets are sourced from the wild. This puts pressure on the survival of the plants, due to their rampant harvesting and consumption. The high trade in the plants is driven by low socio-economic status of the vendors, such as unemployment, limited skills and impoverished livelihoods [7]. Moreover, commercial traditional herbal mixtures produced in the country have recently been documented by [8]. This study reported 49 commercial medicinal products, a majority of which are developed from plants. However, the study neither documented nor provided information on the plants used for development of these commercial products. Moreover, [8] focused mainly on herbal products used in traditional medicine. It is also important to note that new commercial products continuously enter the market, particularly because there is no specific legislation regulating the production of these mixtures in the country. Furthermore, even though Lesotho's legislation regulates harvesting of some of the plants, its implementation is limited, thus harvesting of the plants is poorly controlled.

On the other hand, some plant species are being exported as raw materials to countries such as South Africa, Germany, Australia and America. In fact, *Agave americana* and *Rosa rubiginosa* have entered local and international biotrade industries for making useful products for the food, pharmaceutical, and cosmetic industries [9]. For example, Lesotho is currently exporting *R. rubiginosa* fruits to Germany, which are used for making tea and jam, as well as production of essential oils used in the cosmetics industry. The remaining residue is reported to induce fertility in animals [9]. Moreover, different *Merxmuellera* species are exported to Germany as raw materials, whereas they are used locally to produce various crafts. Even though plants traded as raw materials in the country's informal medicine markets, as well as commercial products developed from these medicinal plants, have been profiled, plants used specifically for development of different commercial products in Lesotho have hitherto not been recorded. The aim of the study was therefore to document these commercially important plants in the country, as well as their pharmacological profiles and conservation statuses. The study will provide information needed by environmental regulating authorities in the country to ensure sustainable utilisation of the plants.

2. Materials and Methods

A physical survey was undertaken in different parts of Maseru District (the capital and main town) of Lesotho between January 2019 and October 2021, taking a record of existing commercial products developed from plants (as reflected in their lists of ingredients). A map of the study area is shown in Figure 1. Moreover, a literature review was conducted on the pharmacological activity, phytochemical composition, cytotoxicity and conservation statuses of these plants. The therapeutic and safety assessment (pharmacological, phytochemical and cytotoxitcity) is important because a majority of the plants are used for development of medicinal products. In terms of conservation statuses of the plants, the International Union for Conservation of Nature (IUCN) Red List for Lesotho flora is outdated, having been last updated in 2002. Therefore, the current survey relied on the South African Red List website [10]. This is because South Africa completely surrounds Lesotho and shares similar vegetation. The Ministry of Small Business, Cooperatives and Marketing was consulted to source information on products that are commercialised from plants. Information was also sourced from the Ministry of Trade and Industry, as well as the Lesotho Revenue Authority regarding licensing of such commercial products. The Ministry of Tourism, Environment and Culture also provided information on plants that are harvested and exported as raw materials. Additional information was gathered by listening to the local radio stations where some of the commercial products are advertised.

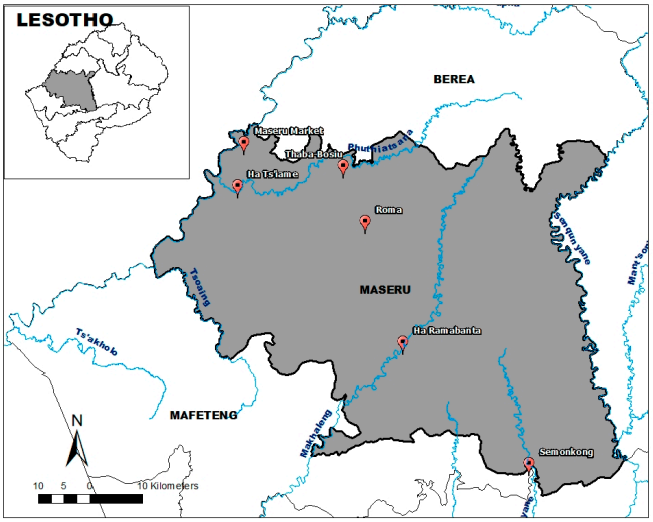

Figure 1. Map of the study area (source: L. Motjotji).

3. Results

Fifteen plants of commercial importance in Lesotho are recorded in the current study, namely *Agave americana* L., *Aloe ferox* Mill., *Aloiampelos striatula* (Haw.) Klopper & Gideon F.Sm., *Artemisia afra* Jacq. ex Willd., *Cannabis sativa* L., *Eucalyptus rubida* H. Deane & Maiden, *Helichrysum odoratissimum* (L.) Sweet, *Hermannia depressa* N.E.Br., *Hypoxis hemerocallidea* Fisch. & C.A. Mey, *Ledeuboria cooperi* (Hook.f.) Jessop, *Mentha* spp. (*M. aquatic L.*, *M. longifolia* (L.) Huds., *Merxmuellera* spp. (*M. macowani*, *M. drakensbergensis*), *Pelargonium sidoides* DC., *Opuntia ficus-indica* (L.) Mill., *Rosa rubiginosa* L. and *Urtica urens* L. (Table 1). Pharmacological assessment has previously been undertaken on a majority of these plants, most of which were found to be active against relevant disease-causing microorganisms, providing validation for their medicinal use (Table 1). Conservation statuses of the plants are also provided, except for the six alien/exotic plants (marked with an asterisk in Table 1), some of which are also invasive (marked with #). The different plants (Figure 2) and their resultant commercial products are shown in Figures 3 and 4.

Table 1. A summary of commercially important plants of Lesotho, their biological activity and conservation statuses.

Plant Species (with Common and Vernacular Names in Brackets)	Ethnobotanical Uses	Plant Part Used	Pharmacological Activity (Antimicrobial, Anti-Inflammatory)	Phytochemical Composition	Toxicity	Conservation Statuses	Commercial Products Developed from the Plant	References
* # *Agave americana* (Century plant, Lekhala-le-leputsoa)	Skin problems (herpes sores/ulcers), sore feet, bruises, purgative, rheumatism, syphilis	Leaves	Antimicrobial activity: Active against *Bacillus subtilis, Staphyllococcus aureus, Salmonella choleraesuis* Anti-inflammatory activity: Oedema assay: 81% inhibition at 6 mg/ear	Flavonoids, saponins, glycosides, triterpenes, steroids, glycosides	Acute irritant contact dermatitis, also toxic to freshwater snail	Not Evaluated	Cosmetic products and herbal medicine	[11–19]
Aloe ferox (Bitter aloe, Lekhala-la-Quthing)	Skin problems (eczema, herpes, shingles, burns sores/ulcers), hair treatment, circulatory, digestive (laxative), eye problems, degenerative (diabetes, high blood pressure, arthritis, diabetes) STIs, sinusitis, bile problems	Leaves	Antimicrobial activity: Noteworthy activity against *Neisseria gonorrhoea, Candida albicans* MIC assay against *C. albicans* (>1.00 mg/mL), *Gardnerella vaginalis* (>1.00 mg/mL), *N. gonorrhoeae* (0.50 mg/mL) *Oligella ureolytica* (1.00 mg/mL), *T. vaginalis* (>1.00 mg/mL), *Ureaplasma urealyticum* (>1.00 mg/mL) Anti-inflammatory activity: Oedema assay: 78.2% inhibition at 400 mg/kg; 72.1% at 100 mg/kg	Aloin, anthraquinones, glycoproteins, Phenols, alkaloids, quinones, anthrones, chromones, proanthocyanidins, pyrones, flavonoids, saponins, fatty acids, phytosterols, pyrimidines, alkanes	Generally considered safe. However, causes dose-dependent apoptosis involving mitochondria in Jurkat cells	Least Concern	Cosmetic products	[11,13,16,20–33]

Table 1. *Cont.*

Plant Species (with Common and Vernacular Names in Brackets)	Ethnobotanical Uses	Plant Part Used	Pharmacological Activity (Antimicrobial, Anti-Inflammatory)	Phytochemical Composition	Toxicity	Conservation Statuses	Commercial Products Developed from the Plant	References
Artemisia afra (African wormwood, Lengana)	Respiratory ailments (coughs, colds, influenza, sore throats), digestive (intestinal worms, stomach complaints, worms, constipation), reproductive (menstrual chill, childbirth), earache, malaria, loss of appetite, headache, toothache, gout	Leaves	MIC assay against *Mycobacterium smegmatis* (1.60 *mg/mL), M. tuberculosis* (not active); *M. aurum* (MIC = 1560 µg/mL); *Klebsiella pneumoniae* (0.52 mg/mL), *Moraxella catarrhalis* (2.00 mg/mL), *Pseudomonas aeruginosa* (activity not noteworthy), *Staphylococcus aureus* (0.25 mg/mL) (Antibacterial activities (MIC) against *Escherichia coli, Klebsiella. pneumoniae, Staphylococcus aureus, Mycobacterium. aurum Bacillus cereus;* Antibacterial activities (MIC & disc diffusion assay) against *Bacillus subtilis*,; anthelmintic activity against *Caenorhabditis elegans* (McGaw, 2000); anti-amoebic activity (anthelmintic assay) against *Entamoeba histolytica*; Antimicrobial activities (MIC) against *S. aureus, S. epidermidis, Pseudomonas aeruginosa, Enterobacter cloacae, K. pneumonia, Escherichia coli*; Antibacterial activity (Disc-diffusion assay & MIC) against *Staphylococcus aureus, Bacillus subtilis;* antibacterial activity (MIC) against *S. epidermis*	Acetylenes, camphor, coumarins, flavonoids, lactones, polyacetylenes, tannins, terpenoids, thujone	Non-toxic, causes no apparent organ damage, and in high doses may have a hepatoprotective effect in mice; however, some kidney functions may be compromised at high dosages of the extract	Least Concern	Herbal teas and remedies	[13,23,25,34–50]

Table 1. *Cont.*

Plant Species (with Common and Vernacular Names in Brackets)	Ethnobotanical Uses	Plant Part Used	Pharmacological Activity (Antimicrobial, Anti-Inflammatory)	Phytochemical Composition	Toxicity	Conservation Statuses	Commercial Products Developed from the Plant	References
* *Cannabis sativa* (Hemp, Marijoana, Matekoane)	Treatment of pain, rheumatism, asthma, glaucoma, nausea, multiple sclerosis, depression, cancer, lack of appetite associated with HIV/AIDS, constipation, fatigue, rheumatism, malaria, wound healing, gastrointestinal diseases, insomnia, pain, snake bite, anodyne, sedative, tonic and narcotic	Leaves, seeds	Antibacterial properties against *Escherichia coli*; anti-malarial and anti-leishmanial effects; preclinical and clinical studies for anticonvulsant effects	Cannabinoids (e.g., tetrahydrocannabinol-THC, cannabidiol -CBD, cannabichromene –CBC, cannabigerol -CBG), terpenes, flavonoids, alkaloids	Smoke contains mutagenic carcinogenic and teratogenic substances. Acute toxicity, particularly when inhaled e.g., LD_{50} values for THC are 43 mg/kg for mouse, 455 mg/kg for rat; in vitro and in vivo preclinical findings demonstrate neuroprotection against amyloid beta (Aβ) toxicity and neuronal death; THC has bronchodilation and hypotensive effects, and high doses can cause anxiety, panic fears, tremors, psychotic aggressiveness, nausea, vomiting and tachycardia	Not Evaluated	Herbal medicine, cosmetic products	[25,33,51–53]
* *Eucalyptus rubida* (Candlebark, ribbon gum or white gum, Boloukomo)	Flu, colds, asthma, nasal congestion	Leaves	TB: MIC assay against *M. smegmatis* (activity not noteworthy); Other RTIs: MIC assay against *K. pneumoniae* (0.67 mg/mL), *M. catarrhalis* (0.83 mg/mL), S. aureus (0.13 mg/mL)	Coumarins, flavonoids, terpenoids	Essential oils toxic to *Haematobia irritans*	Not Evaluated	Extraction of oils for therapeutic purposes (Eucalyptus oil)	[54–57]

Table 1. *Cont.*

Plant Species (with Common and Vernacular Names in Brackets)	Ethnobotanical Uses	Plant Part Used	Pharmacological Activity (Antimicrobial, Anti-Inflammatory)	Phytochemical Composition	Toxicity	Conservation Statuses	Commercial Products Developed from the Plant	References
Helichrysum odoratissimum (Most fragrant helichrysum, Phefo)	Coughs, flu, colds, headache, menstrual pains, backache, emetic for excessive bile, abdominal pains, heartburn	Shoots	MIC assay against *Mycobacterium aurum* (0.68 mg/mL), *M. smegmatis* (0.50 mg/mL), *M. tuberculosis* (0.50 mg/mL and 0.30 mg/mL); MIC assay against *K. pneumoniae* (2.0 mg/mL), *M. catarrhalis* (0.25 mg/mL), *P. aeruginosa* (0.5 mg/mL), *S. aureus* (0.125 mg/mL) anti-inflammatory activity of 5,6-dihydroxy-3,7,8-trimethoxyflavone and 3′,4′,3,5-tetrahydroxy-7-methoxyflavone	Flavonoids, helichrysetin, pyrenes terpenoids	No toxicity using sulforhodamine B assay, with 17.5% T/C of Graham cells, 48.2% T/C of SF-268 cells, 7.4% T/C of MCF-7 breast cancer cells	Least Concern	Herbal teas	[11,13,21,23,58–64]
Hermannia depressa (doll's roses, Selenjane)	Stomach ache, nausea, diarrhoea, heartburn, colic, improves appetite in pregnant women, coughs, cancer, wounds, bruises		MIC assay against *Bacillus subtilis* (1.56 mg/mL in leaf, 0.39 mg/mL in stem, 0.195 mg/mL in root); *E. coli* (0.78 mg/mL in leaf, 3.125 mg/mL in stem, 0.78 mg/mL in root); *K. pneumoniae* (0.78 mg/mL in leaf, 3.125 mg/mL in stem, 0.78 in root), *S. aureus* (0.78 mg/mL in leaf and stem, 3.125 mg/mL in root); MIC assay against *M. tuberculosis* (0.78 mg/mL)	Tannins, saponins, phenols	No significant toxicity in bovine cells using brine shrimp lethality test as well as MTT and LDH cytotoxicity assays	Least Concern	Herbal mixtures	[65–67]

Table 1. *Cont.*

Plant Species (with Common and Vernacular Names in Brackets)	Ethnobotanical Uses	Plant Part Used	Pharmacological Activity (Antimicrobial, Anti-Inflammatory)	Phytochemical Composition	Toxicity	Conservation Statuses	Commercial Products Developed from the Plant	References
Hypoxis hemerocallidea, African potato (Moli)	Dizziness, cancers, inflammations, mental disorders, human immunodeficiency virus (HIV), bladder disorders, burns, prostrate problems, testicular tumours, urinary infections, headache	Corm	Antimicrobial activity (MIC) against *Candida albicans, Ureaplasma urealyticum, Gardnerella vaginalis, Trichomonas vaginalis, Neisseria gonorrhoeae* (Naidoo et al., 2013); antinociceptive (using hot plate, acetic acid analgestic test methods in mice), MIC assay against *M. smegmatis* (activity not noteworthy), MIC assay against *K. pneumoniae* (0.40 mg/mL in corm), *M. catarrhalis* (activity not noteworthy), *S. aureus* (0.40 mg/mL in leaf and corm); anti-inflammatory and antidiabetic activities Anti-inflammatory activity: Cyclooxygenase assay: 48% COX inhibition; 98%COX-1 and COX-2 74% inhibition at 250 µg/ml in corm, and 78% COX-1 and 59% COX-2 in leaf	Terpenoids, saponins, glycosides, tannins, phenolic compounds, terpenes, flavonoids, phytosterols, sterols, sterolins	Low toxicity in mice at low doses, APE < 1600 mg/kg; hypoxosides nontoxic to parental MCF-10A cells No genotoxicity using the neutral red uptake (NRU) assay	Least Concern	Traditional herbal mixtures	[68–75]
Ledebouria cooperi (Cooper's African hyacinth, Leptjetlane)	Digestive (constipation and diarrhoea in children), phlegm, reproductive, skin problems, cleanses blood, soothing medicine for women during pregnancy	Bulb	Not yet evaluated	Flavonoids, terpenoids	Highly poisonous, capable of inducing a comatose state in children, as well as a number of symptoms associated with cardiac glycoside activity	Least Concern	Herbal mixtures	[21,59,60,76]

Table 1. *Cont.*

Plant Species (with Common and Vernacular Names in Brackets)	Ethnobotanical Uses	Plant Part Used	Pharmacological Activity (Antimicrobial, Anti-Inflammatory)	Phytochemical Composition	Toxicity	Conservation Statuses	Commercial Products Developed from the Plant	References
Mentha spp. *(M. aquatica, M. longifolia* (Mint, Koena)	Beverage (tea); medicinal (circulatory, respiratory, reproductive (virility in men), sore joints	Leaves	MIC assay against *M. aurum* (2.0 mg/mL), *M. smegmatis* (0.50 mg/mL), *M. tuberculosis* (1.00 mg/mL), *K. pneumoniae* (31.25 µm/ml and 1 mg/mL), *M. catarrhalis* (4.00 mg/mL), *P. aeruginosa* (2.00 mg/mL), *S. aureus* (15.62 µm/mL, 1.00 mg/mL); Disc diffusion method against *K. pneumoniae* (14 mm inhibition zone), *P. aeruginosa* (no inhibition), *S. aureus* (13 mm inhibition zone) Anti-inflammatory effect (300 µg/cm) provoked oedema reductions ranging from 21 to 27% Decreased TNFα pro-inflammatory cytokine expression	Alkaloids, flavonoids, glycosides, phenols, Tannins, terpenoids	Acute toxicity using the Microtox Acute Toxicity Test revealed 20% toxicity for human health Moderately toxic for oral medication in rats, with LD50 of 470 mg/kg; marked cytotoxic activity against MCF-7 cells using brine shrimp cytotoxicity assay	Least Concern	Herbal teas	[77–81]
Merxmuellera spp. (Broom grass, mountain wire, Moseha)	Crafts (brooms, baskets, mats, hats)	Shoots					Traditional Basotho hats, mats, brooms, baskets, beer strainers, milk whisks and ropes. The raw material is also exported	[22,82,83]
**# Opuntia ficus-indica* (Sweet prickle pear, Indian fig, Torofeie)	Food (fruits); digestive (constipation), toothache, piles, musculoskeletal	Leaves	Ripe fruits are an excellent source of minerals (especially calcium and magnesium) as well as vitamin C	Sterols, carotenes, vitamins	Cladodes are poisonous to livestock when consumed in large quantities	Not Evaluated	Beverages (e.g., fruit juices), cosmetic products	[84,85]

Table 1. *Cont.*

Plant Species (with Common and Vernacular Names in Brackets)	Ethnobotanical Uses	Plant Part Used	Pharmacological Activity (Antimicrobial, Anti-Inflammatory)	Phytochemical Composition	Toxicity	Conservation Statuses	Commercial Products Developed from the Plant	References
Pelargonium sidoides (African geranium, Khoara)	Respiratory tract infections (TB, bronchitis, pneumonia), digestive, (diarrhoea, constipation, worms, dysentery) reproductive (heartburn in pregnant women)		Antimicrobial activity (MIC) against *Bacillus cereus, Staphylococcus epidermidis, S. aureus, Micrococcus kristinae, Streptococcus pyogenes, Salmonella pooni, Pseudomonas aeruginosa, Klebsiella pneumonae*; Antimicrobial activity (MIC) against *Haemophilus influenza, Moraxella catarrhalis, Streptococcus pneumoniae*. Antifungal activity against *Aspergillus niger, Fusarium oxysporum, Rhizopus stolonifer*; Antibacterial activities (MIC) against *Staphylococcus aureus, Streptococcus pneumonia, Escherichia coli, Klebsiella pneumonia, Proteus mirabilis, Pseudomonas aeruginosa*; EPsR 7630 assessed in acute bacterial bronchitis model in rats, tracheal lesions significantly reduced at doses of 30 and 60 mg/kg.	Coumarins, flavonoids, phenolic acids, tannins, terpenoids	The half maximal cytotoxic concentration of EPs 7630 (CC50) of 557 mg/mL; EPss 7630, did not cause obvious toxic effects in mice (lungs, liver, spleen, kidneys),	Least Concern	Herbal mixtures	[86–92]

Table 1. *Cont.*

Plant Species (with Common and Vernacular Names in Brackets)	Ethnobotanical Uses	Plant Part Used	Pharmacological Activity (Antimicrobial, Anti-Inflammatory)	Phytochemical Composition	Toxicity	Conservation Statuses	Commercial Products Developed from the Plant	References
*# *Rosa rubiginosa* (Rosehip, 'Morobobei)	Scars, burns	Fruits	High values of DPPH inhibition confirm antioxidant activity	Fat-soluble vitamins (particularly vitamin C), b-carotene, phenols, fatty acids, lipids, sterols, a high content of transretinoic acid	Skin irritation	Not Evaluated	Herbal teas and fruit juices	[93–95]
* *Urtica urens* (small needle, Bobatsi)	Food (young leaves); medicinal (degenerative-diabetes, STIs, snake bite, immune booster), wounds, asthma, stomach ulcers, heartburn, cleansing bladder	Leaves	Antimicrobial activity: No activity against *E. coli*, *P. aeruginosa*, *S. aureus*, *S. pyogenes*, *C. albicans*; Anti-inflammatory activity: Oedema assay: 41.5% inhibition at 300 mg/kg	Alkaloids, glycosides, saponins, tannins	Oedema assay: 41.5% inhibition at 300 mg/kg	Not Evaluated	Cosmetic and herbal juices	[11,21,96,97]

* designates exotic/alien plants; # denotes invasive plants.

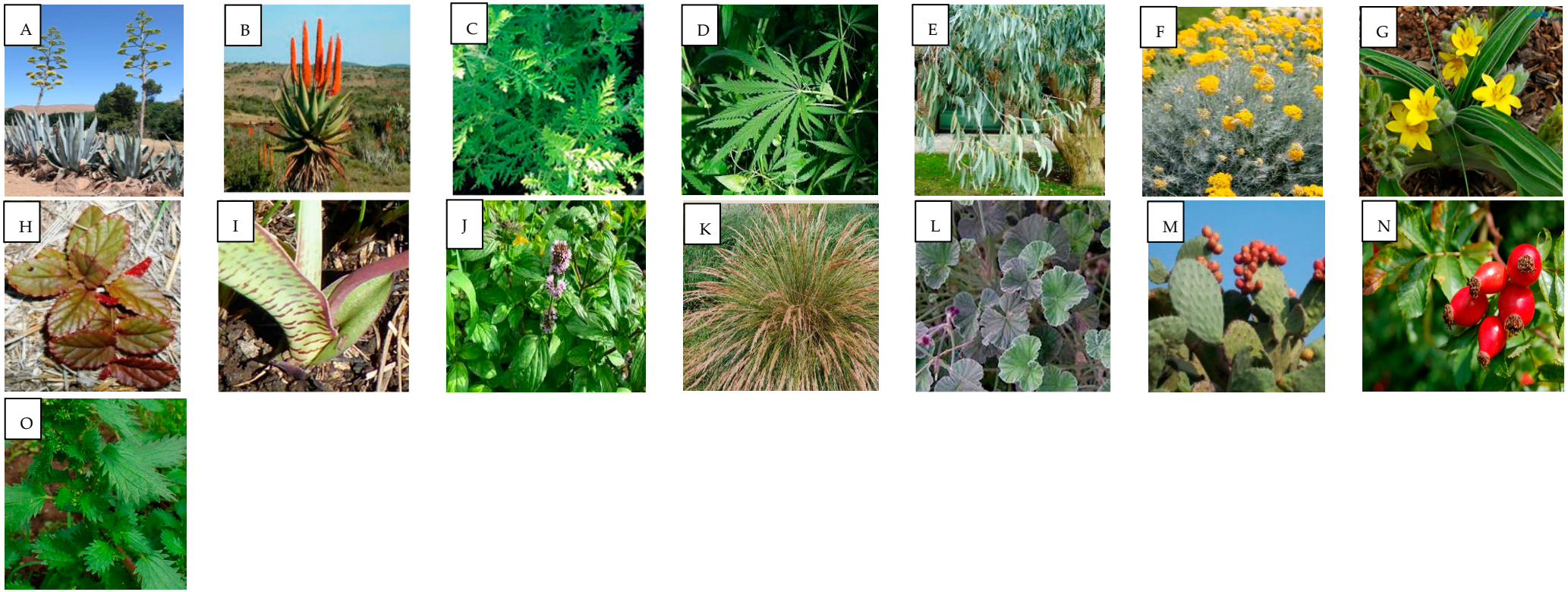

Figure 2. Plants used for development of various commercial products in Lesotho: (**A**) *Agave americana*, (**B**) *Aloe ferox*, (**C**) *Artemisia afra*, (**D**) *Cannabis sativa*, (**E**) *Eucalyptus rubida*, (**F**) *Helichrysum odoratissimum*, (**G**) *Hypoxis hemerocallidea*, (**H**) *Hemannia depressa*, (**I**) *Ledebouria cooperi*, (**J**) *Mentha* sp., (**K**) *Merxmuellera* sp., (**L**) *Pelargonium sidoides*, (**M**) *Opuntia ficus-indica*, (**N**) *Rosa rubigonosa*, (**O**) *Urtica urens* (Source K. Kobisi & L. Seleteng-Kose).

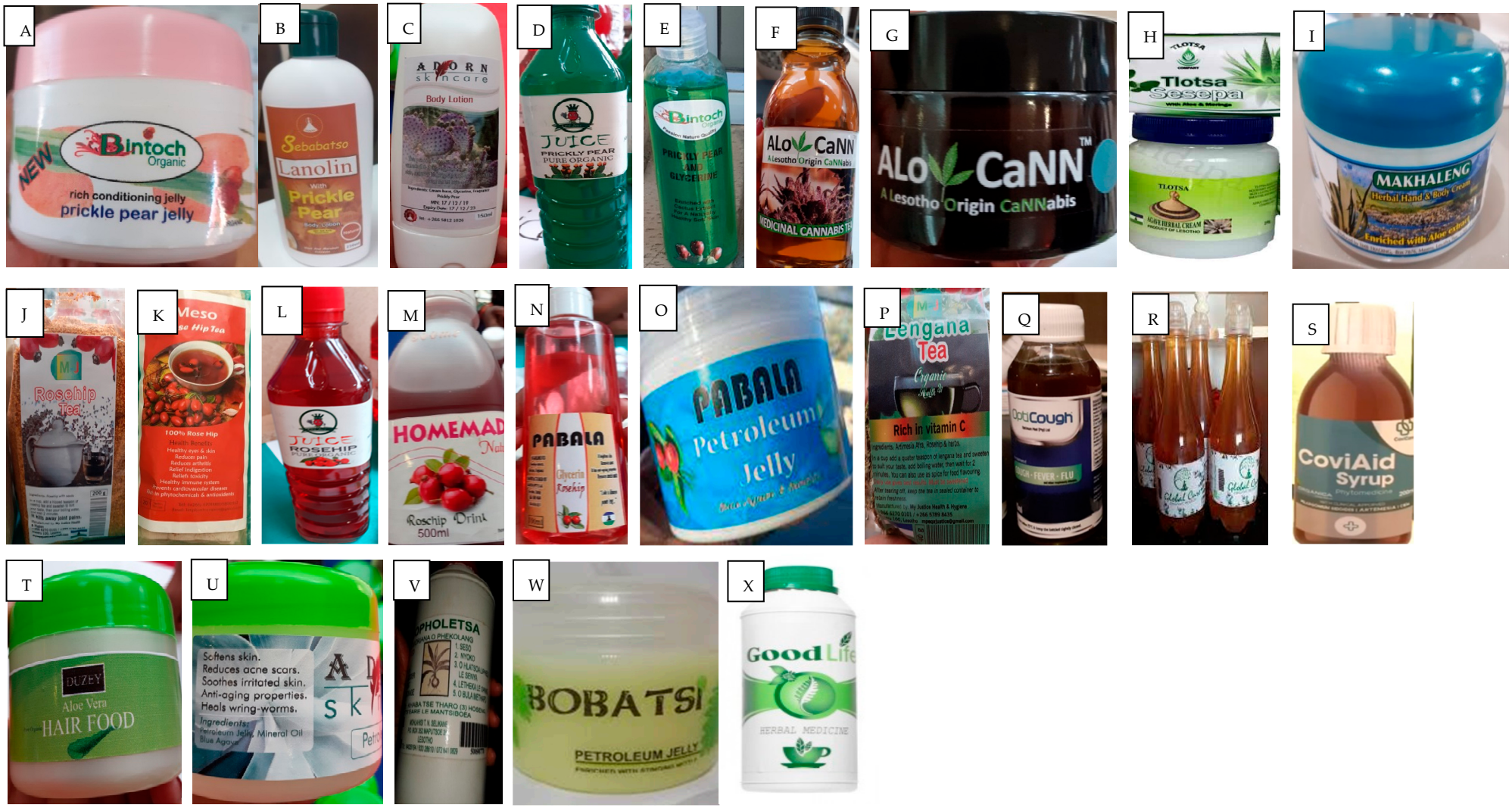

Figure 3. Some of the commerical products developed in Lesotho using different plants: (**A**–**E**) *Opuntia ficus-indica*, (**F**,**G**) *Cannabis sativa*, (**H**,**I**) *Agave americana*, (**J**–**O**) *Rosa rubiginosa*, (**P**–**S**) *Artemisia afra*, (**T**,**U**) *Aloe ferox*, (**V**) *Ledebouria cooperi*, (**W**) *Urtica urens*, (**X**) *Hypoxis hemerocallidea*. Source: L. Seleteng-Kose & P. Likoetla.

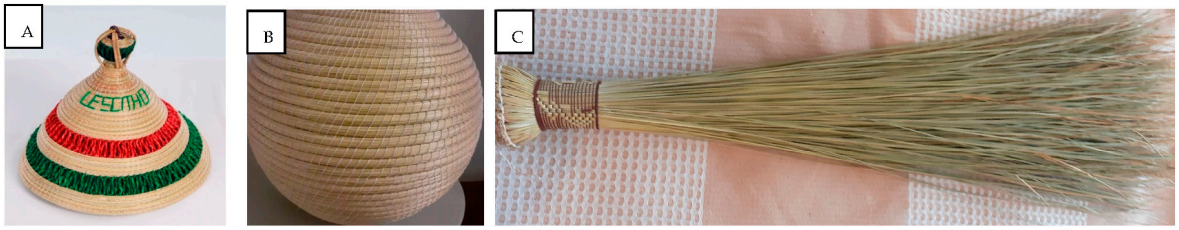

Figure 4. Some of the crafts produced from *Merxmuellera* spp.–a traditional Basotho hat (**A**), basket (**B**) and broom (**C**); source (L. Seleteng-Kose).

4. Discussion

The major commercial products developed from the 15 recorded plants are cosmetic products, beverages and traditional herbal mixtures used for treatment of various ailments (Figure 3), as well as crafts (Figure 4). The traditional herbal mixtures have recently been documented by [8]. The products are sold in major towns (traditional medicine markets and streets) by herbalists, traditional practitioners and street vendors. The study provided the therapeutic uses of the products, a list of ingredients, route of administration/dosage, packaging and shelf life of the products. Surprisingly, some commercial products do not display a list of ingredients used, hence it is possible that some products have used plants, even though they are not indicated. Moreover, some commercial products are not licensed, hence are not documented under the Ministry of Trade and Industry. Indeed, [3] argues that bureaucracy and regulations may have a negative impact on the innovation and commercialisation of African medicinal plants. Even though there is a tremendous potential for commercialisation of under-utilised African plants especially in functional foods and nutraceuticals, the main constraint is the identification, isolation and extraction of bioactive compounds from the plants [2].

Of the 15 plants documented in the current study, four (*A. ferox*, *A. afra*, *P. sidoides* and *H. hemerocallidea*) have been reported by [97] as indigenous medicinal plants of interest in product development in South Africa and elsewhere. In addition, two other plants (*C. sativa* and *H. odoratissimum*) have been included among the most prominent and well-known African medicinal plants by [3]. The same study also lists these plants as species of commercial interest in the international pharmaceutical and nutraceutical industries (except for *H. odoratissimum*). Furthermore, [98] reported *P. sidoides* to be well positioned for commercial growth, particularly because it has clinical evidence of being a safe and efficacious remedy. However, in Lesotho, where processing is limited and markets are not developed, this plant is harvested by local communities and sold in its raw form to international pharmaceutical companies, including in neighbouring South Africa, where it is widely commercialised for a bio-active substance found in its lignotubers. Since the 1990s, a prodelphinidin-rich ethanolic extract, made from the tuberous roots of *P. sidoides* (called EPs 7630), licensed to treat respiratory tract infections such as acute bronchitis, has become one of the most successful phytomedicines in the world [89,99]. Indeed, the tuberous roots of the plant are reported to be the raw material for an important German phytomedicine used for treatment of upper respiratory tract infections and acute bronchitis [100]. A preparation of *P. sidoides* tincture is marketed in different countries such as Ukraine, Russia and Latvia [88]. Proprietary extracts of *P. sidoides* and their preparations, as well as the use thereof, were protected by about seven patents worldwide in 2010 [101].

Even though a limited number of commercial products are produced from *P. sidoides* in the country, it is exported as a raw material to Germany. The plant is locally used in traditional medicine for the treatment of digestive, respiratory and reproductive ailments [11,12,22,23,81,82]. The plant is used for similar purposes by the Zulus (in South Africa) for the treatment of diarrhoea, dysentery and gonorrhea [13]. Indeed, *P. sidoides* has been well studied, and its roots have been found to have antimicrobial and immunomodulating activity, as well as clinically proven effects on the mucociliary system and on malaise [98]. It is therefore not surprising that *P. sidoides* has entered the pharmaceutical

industry, where it forms part of the ingredients used in the manufacturing of Linctagon, a South African product used in the treatment of respiratory ailments. In addition, the plant is a key ingredient in a German medicinal remedy called Umckaloabo, which is used mainly to treat bronchitis [23].

Hypoxis hemerocallidea is considered an important plant species in traditional medicine in southern Africa, including Lesotho, and the use of its corms is so popular that the species is threatened by overharvesting from its natural habitats. A study by [12] reported the plant to be among the top 10 commonly used plant species in Maseru District, Lesotho. The plant was also found to be one of the top 10 most frequently sold plant species, with approximately 11,000 kg/year sold in South Africa, valued at ZAR 322 500 (South African Rand) [102]. Similarly, [7] established that *H. hemerocallidea* is one of the most commonly traded species in the local traditional medicine markets of Lesotho, being in the top seven. Infusions of the mature corms of the plant are used in African traditional medicine as emetics, to treat dizziness, burns, wounds, wasting disease, anxiety, depression and insanity, diabetes mellitus, cancer, polyarthritis, hypertension and asthma [73,103,104]. Botanical products of this species are formulated and marketed for the amelioration of prostate disorders (benign prostate hypertrophy (BPH) in particular) and urinary infections, as well as immunomodulation [105,106]. It is believed that the phytosterols in *Hypoxis* species, with their recognized 5α-reductase and aromatase inhibition activity, are responsible for amelioration of BPH. These sterols have also been shown to possess immune modulating properties, which may have some use in tuberculosis treatment [107]. Anti-inflammatory and anti-diabetic properties have been demonstrated with aqueous extracts in mice and rats [73,108]. There are also reports that extracts of *Hypoxis* stabilise CD4 lymphocytes in HIV/AIDS [109].

Urtica urens has only recently been commercialised, where the plant is used for development of cosmetic products and juices. The plant is used medicinally for the treatment of asthma, stomach ulcers and heartburn, as well as to cleanse the bladder [21]. In addition, the plant is used as an immune booster and in the treatment of diabetes and herpes, as well as a remedy for snake bites [22]. The young plant shoots are cooked and eaten as vegetables and are reported to have significant quantities of vitamins A and C [83]. The leaf nettles surpass spinach in their nutritional value, being rich in protein and minerals, particularly potassium, magnesium, calcium, copper, phosphorus and iron [58,83]. On the other hand, even though few commercial products have been developed from *Mentha* species in Lesotho, its global market is very large, where it is extensively used in various pharmaceutical, cosmetic and flavoring industries [110,111]. Indeed, *Mentha* species are reported to have contributed revenue of about USD150.9 million in Washington in 2013 [112].

The top five plants with the highest potential for successful commercialisation in Lesotho were found to be *Rosa rubiginosa, Opuntia ficus-indica, Agave americana, Cannabis sativa* and *Artemisia afra* (in descending order). This is based on the numerous commercial products developed from such plants (Figure 2). The properties of *R. rubiginosa* are attributed to the considerable vitamin C content detected in the fruit (400 mg/100 g), which is 10 times higher than in orange juice [92]. Moreover, oil and fibre fractions, as well as other non-oily extracts found in *R. rubiginosa,* contribute to the well-known therapeutic and pharmacological effects of the plant. For example, the plant contains phenolic compounds with antioxidant properties [93], as well as a high content of transretinoic acid, having effective influence on antipsoriases, healing and anti-keratosis processes. As a result, body creams containing *R. rubiginosa* oil are used as a skin regenerating treatment in scars and burns [113]. In fact, the high values of the DPPH inhibition percentage of extracts confirm *R. rubiginosa* as a good and cheap source of antioxidant substances [92]. It is therefore not surprising that the plant is finding increasing applications as an active part of the cosmetic industry in Lesotho. Similarly, a wide range of commercial products have been developed from *O. ficus-indica*, ranging from cosmetics to beverages. Even though the plant originates from Central America, it is currently widespread in Lesotho, being abundant in rocky hills

of lowlands and foothills [84]. The fruit is reported to have astringent properties and is thus used in Mexico for treatment of burns, wounds and oedema [114]. It is therefore not surprising that the plant is used in Lesotho to manufacture cosmetic products such as body lotions (pers. obs.).

On the other hand, even though *C. sativa* has been widely grown and used in Lesotho since time immemorial, the country only legalised the use of the plant in 2017, becoming the first African country to legalise its cultivation for medical use. However, its cultivation, export and import are only permitted to companies with licenses. These licenses are very expensive, costing around LSL 500,000 (Lesotho Loti = USD 29 761) annually on acquisition, even though the price goes does upon renewal. Therefore, a limited number of companies (around 43) have been awarded licenses to produce medical *Cannabis* in Lesotho, even though only five are currently operational. Lesotho is reported to provide the best habitat for growing *Cannabis*, "mainly due to its unique topography with mineral rich soils, natural spring waters and high altitudes" [115]. The country is currently the main producer of medical *Cannabis* in the African region. This move has attracted foreign investment in the area of medical *Cannabis* production in the country [116]. Consequently, various commercial products developed from the plant have been observed, particularly in the Maseru District.

Traditional herbal mixtures, particularly those used for treatment of respiratory ailments, have recently become popular, due to the onset of COVID-19. Many of these mixtures are derived from *A. afra*, and thus the plant is currently heavily harvested from its wild habitats across the country (pers. obs.). This may be attributed to the fact that the plant is renowned for the treatment of respiratory tract ailments in Lesotho, such as coughs, colds and flu, most of which are associated with COVID-19. The plant is also used for similar purposes in other parts of southern Africa, such as South Africa [13]. However, *A. afra* has recently been reported to be invasive in some parts of Lesotho, contributing to rangeland degradation [117].

Among the 15 recorded plants of commercial importance, *Merxmuellera* species are the only ones used for production of non-consumables, namely crafts such as traditional Basotho hats (*mokorotlo*), brooms, floor mats, baskets, beer strainers, milk whisks and plaited ropes (Figure 4). In addition, the species are used for thatching, particularly in the rural areas of Lesotho. These grass species include *M. disticha*, *M. drakensbergensis*, *M. macowanii* and *M. stereophylla.* Shoots, particularly the leaves, are the main plant parts used for development of the crafts, due to their stiff and strong nature. Most of the crafts are sold to tourists visiting the country (pers. obs.). The plants are also used for similar purposes in Qwaqwa in the Free State Province of South Africa. Cut bundles of *M. drakensbergensis* were reportedly exported to Australia for production of yard brooms [118].

Even though there is extensive knowledge of medicinal uses of plants, identification of bioactive plant compounds and their properties needed to inform pharmaceutical industries is still a challenge in the country. Therefore, commercially oriented research is needed to determine appropriate candidates for the food, cosmetic and pharmaceutical industries. Some research and development are being undertaken mainly at the National University of Lesotho and Agricultural Research Division of the Ministry of Agriculture and Food Security. However, the main challenges hindering progress are lack of equipment, inadequate technical expertise, limited infrastructure and inadequate financial resources to carry out research effectively. On the other hand, some of the indigenous plants being used are rapidly declining. The pressure on plants emanates from the fact that, in the past, harvesting of medicinal herbs was primarily done by traditional healers. However, the demand has increased due to the plants becoming a cheaper alternative source of income [119]. Five of the recorded plants are declared legally protected in the country, namely *P. sidoides*, *Mentha* spp., *L. cooperi*, *Merxmuellera* spp. and *H. hemerocallidea* [120], even though they are continuously harvested. Therefore, implementation of legislation should be prioritised, as well as propagation of the indigenous plants of commercial importance to ensure their conservation and sustainable use. Indeed, [121] indicated that farming overharvested species is a conservation strategy that can meet the growing market demand

and conserve wild populations of the target species. Furthermore, [122] reported that suitable post-harvesting techniques are needed to preserve the end product developed from plants. In fact, [123] emphasized that partnership with the nursery industry is important for ex situ plant conservation, to ensure that the propagation and trade of commercial plant species benefits the long-term survival of the species without harming wild populations.

5. Conclusions

Development of commercial products from plants is on the rise in Lesotho, and these include cosmetic products, traditional herbal remedies, beverages and crafts. The study has profiled 15 plants used for development of various commercial products. These are *Agave americana*, *Aloe ferox*, *Artemisia afra*, *Cannabis sativa*, *Eucalyptus rubida*, *Helichrysum odoratissimum*, *Hermannia depressa*, *Hypoxis hemerocallidea*, *Ledeuboria cooperi*, *Mentha* spp. (*M. aquatic, M. longifolia*), *Merxmuellera* spp. (*M. macowani, M. drakensbergensis*), *Pelargonium sidoides*, *Opuntia ficus-indica*, *Rosa rubiginosa* and *Urtica urens*. However, it is possible that there are more products developed from plants, which are not captured in the current study because many commercial products lack lists of ingredients on their labels. Moreover, other commercial products are not listed in the Government's database (Ministry of Small Business, Cooperatives and Marketing, as well as the Lesotho Revenue Authority). Of the 15 profiled medicinal plants, the top three with a high potential for successful commercialisation were found to be *Opuntia ficus-indica*), *Artemisia afra* and *Rosa rubiginosa*. In addition, *Cannabis sativa*, *Pelargonium sidoides*, *Hypoxis hemerocallidea* and *Merxmuellera* spp. are being traded as raw materials to countries such as South Africa, Germany, Australia and America. However, harvesting of these plants is not adequately regulated. Therefore, some of these species are declining, and thus conservation of the commercially important indigenous species should be prioritised. This may be achieved by developing specific legislation regulating development of commercial products from natural resourced-based products in Lesotho. Moreover, propagation of the indigenous plants is recommended. Harvesting of alien, invasive plants such as *Agave americana, Opuntia ficus-indica* and *Rosa rubiginosa* for development of commercial products may help reduce their populations, thereby controlling their invasiveness. However, care should be taken not to spread them further as they are being harvested.

By profiling plants of commercial importance in Lesotho, the study intends to enhance innovative research and development, which are significant in developing commercial products and validating their uses in the food, cosmetics and pharmaceutical industries. In order to sustain commercialisation, the market requires a continuous supply of the plant material. Therefore, there is need to have commercial farms for growing the commonly used plant species to ensure that they do not become extinct. It is recommended that local research institutions should be trained on product development. Furthermore, establishment of partnerships and collaboration between local product developers and international partners is essential.

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