

Tariq Aftab  
Khalid Rehman Hakeem *Editors*

# Medicinal and Aromatic Plants

Healthcare and Industrial Applications

 Springer

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**(1908–1999)**

*A great philanthropist, thinker, visionary, and founder-chancellor of **Jamia Hamdard**, New Delhi, India.*

# Preface

In prehistoric times, humans undoubtedly acquired nature's benefits by discovering medicinal and aromatic plants (MAPs) that were food and medicine. Today, a variety of available herbs and spices are used and enjoyed throughout the world and continue to promote good health. As the benefits from medicinal and aromatic plants are recognized, these plants will have a special role for humans in the future. The enormous demand in botanicals results in a huge trade from local to international level. Until the last century, production of botanicals relied to a large degree on wild collection. However, utilization and commerce of wild plant resources are not detrimental in themselves. For example, the increasing commercial collection, largely unmonitored trade, and habitat loss lead to an incomparably growing pressure on plant populations in the wild. Throughout time, medical care has continually progressed, moving from illnesses to vaccinations and new medicines along with improved healthcare facilities that can more accurately diagnose and treat health problems. Advancements in modern medicine and medical care have enabled people to live longer and healthier lives. New medicines from plant materials and antibiotics from microflora have defeated most diseases. Medicinal and aromatic plants are of high priority for conservation action as wildcrafting will certainly continue to play a significant role in their future trade: the sustainable commercial use of their biological resources may provide a financial instrument for nature conservation. The international market is also quite welcoming for MAPs and essential oils. The increasing environment- and nature-conscious buyers encourage producers to produce high-quality essential oils. There has been growing preference for organic and herbal-based products in the world market. Similarly, the world is shifting from crude export to processing of herbal products and essential oils.

The present book covers a wide range of topics, discussing the role of MAPs in healthcare and their industrial uses. Moreover, this will be a unique reference book on the topic highlighting various healthcare, industrial, and pharmaceutical applications that are being currently used on immensely important MAPs and its future prospects. In this volume, we highlighted the working solutions as well as open problems and future challenges in MAPs research. We believe that this book will

initiate and introduce readers to state-of-the-art developments and trends in this field of study.

The book comprises 27 chapters, most of them being review articles written by experts, highlighting wide range of topics, discussing the role of MAPs in health-care, industry, and their pharmaceutical applications. We are hopeful this volume would furnish the need of all researchers who are working or have interest in this particular field. Undoubtedly, this book will be helpful for general use of research students, teachers, and those who have interest in MAPs.

We are highly grateful to all our contributors for accepting our invitation and for not only sharing their knowledge and research but for venerably integrating their expertise in dispersed information from diverse fields in composing the chapters and enduring editorial suggestions to finally produce this venture. We also thank the Springer Nature team for their generous cooperation at every stage of the book's production.

Lastly, thanks are also due to well-wishers, research students, and authors' family members for their moral support, blessings, and inspiration in the compilation of this book.

Aligarh, India  
Jeddah, Saudi Arabia

Tariq Aftab  
Khalid Rehman Hakeem

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## About the Editors



**Tariq Aftab** received his Ph.D. from the Department of Botany at Aligarh Muslim University, India, and is currently an Assistant Professor there. He is recipient of the prestigious Leibniz-DAAD Fellowship from Germany, Raman Fellowship from the Government of India, and Young Scientist Awards from the State Government of Uttar Pradesh (India) and Government of India. After completing his doctorate, he worked as Research Fellow at the National Bureau of Plant Genetic Resources, New Delhi, and as Postdoctoral Fellow at Jamia Hamdard, New Delhi, India. Dr. Aftab also worked as Visiting Scientist at Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Gatersleben, Germany, and in the Department of Plant Biology, Michigan State University, USA. He is a member of various scientific associations from India and abroad.

He has edited 7 books with international publishers, including Elsevier Inc., Springer Nature, and CRC Press (Taylor & Francis Group), co-authored several book chapters, and published over 50 research papers in peer-reviewed international journals. His research interests include physiological, proteomic, and molecular studies on medicinal and aromatic plants.



**Khalid Rehman Hakeem**, PhD is Professor at King Abdulaziz University, Jeddah, Saudi Arabia. After completing his doctorate (botany; specialization in plant eco-physiology and molecular biology) from Jamia Hamdard, New Delhi, India, in 2011, he worked as a Lecturer at the University of Kashmir, Srinagar, for a short period. Later, he joined Universiti Putra Malaysia, Selangor, Malaysia, and worked there as Postdoctoral Fellow in 2012 and Fellow Researcher (Associate Professor) from 2013 to 2016. Dr. Hakeem has more than 10 years of teaching and research experience in plant eco-physiology, biotechnology and molecular biology, medicinal plant research, plant-microbe-soil interactions, as well as in environmental studies. He is the recipient of several fellowships at both national and international levels; he has also served as a Visiting Scientist at Jinan University, Guangzhou, China. Currently, he is involved with a number of international research projects with different government organizations.

So far, Dr. Hakeem has authored and edited more than 50 books with international publishers, including Springer Nature, Academic Press (Elsevier), and CRC Press. He also has to his credit more than 110 research publications in peer-reviewed international journals and 60 book chapters in edited volumes with international publishers.

At present, Dr. Hakeem serves as an editorial board member and reviewer of several high-impact international scientific journals from Elsevier, Springer Nature, Taylor and Francis, Cambridge, and John Wiley Publishers. He is included in the advisory board of Cambridge Scholars Publishing, UK. He is also a fellow of Plantae group of the American Society of Plant Biologists; member of the World Academy of Sciences; member of the International Society for Development and Sustainability, Japan; and member of Asian Federation of Biotechnology, Korea. Dr. Hakeem has been listed in Marquis Who's Who in the World between 2014 and 2019. Currently, Dr. Hakeem is engaged in studying the plant processes at eco-physiological as well as molecular levels.

# Chapter 19

## Multiple-Usage Shrubs: Medicinal and Pharmaceutical Usage and Their Environmental Beneficiations



Jameel R. Al-Obaidi, Bilal Salim Al-Taie, Muhammed Yahya Allawi, and Khalid H. Al-Obaidi

### 19.1 Jojoba (*Simmondsia chinensis*)

Jojoba (*Simmondsia chinensis*) is dioecious monogenetic grey-green, drought resistant, wind-pollinated shrub (Al-Obaidi et al. 2013), belonging to Simmondsiaceae family, with other common names including lemon leaf, coffee nut, wild hazel and buck nut. Jojoba is almost woody, eternal green, everlasting shrub, producing tiny seeds which contain fluid wax extremely analogous to sperm of whale in prominence (Al-Obaidi 2019).

The origin of *S. chinensis* shrub is the Sonoran Desert of Northern Mexico and the United States in Baja California and South-West Arizona (Azzam et al. 2012), where it is utilized as treatment shrub for different diseases including the healing of wounds, curing some types of ulcers and treatment of skin scratches (Ibrahim et al. 2017). Worldwide, economical value of the plant leading several states such as Argentina, Chile, the Palestinian territories, Egypt, Saudi Arabia, Mexico, India and Australia to cultivate jojoba for more than three decades attributable to economic significance (Abdel-Mageed et al. 2014). *S. chinensis* has waxy esters containing a chain of alcohols and fatty acids (Miklaszewska and Banaś 2016).

Jojoba roots can permeate into 4–5 m deepness, and this elongating shape of root enables them to survive in arid circumstances, and leaves are oval 20–30 mm long

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and 10–15 mm wide, blue-green or grey-green, leather in shape and elongated (Ashour et al. 2013). In a normal environment, *S. chinensis* can tolerate high temperatures and dehydration and, therefore, may be classified as a xerophytic plant (Arya and Khan 2016). Commonly male shoots begin to flower more early than female; the flower originates through the second year of plant development (Ince and Karaca 2011). Flowers are small, green to yellow, 5–6 protecting sepals without petals, female flower initiates independently at another branching node, soft green with elongated sessile with no insects attracting odour in female, meantime the male flowers arise as clusters (Ibrahim et al. 2017). Jojoba grows in tough, sandy soil that allows water to drain at a moderate rate and without water in 5–8 pH. Furthermore, the shrub prefers highly sanded soil with minimum organic materials; also it can resist salinity conditions, with minimum or no fertilization (Aldababseh et al. 2018). Jojoba grows in rainfall standards of 220–400 mm/year (Al-Hamamre 2013). Soil temperature is around 20 °C, and the plant can grow in high temperature, the optimum being 27–33 °C (El Mogy 2012). Extremely low temperature below –3 °C particularly at flowering may kill new seedling plantations, although mature saplings may combat frozen temperatures and the frost may not affect their viability but may decrease yield (Sandouqa and Al-Hamamre 2019). Reproduction of jojoba may be via seed, which is the simplest and more inexpensive process resulting in more male than females; the ratio may reach 5:1 (Inoti 2017), another propagation methods by tissue cultures (Eed and Burgoyne 2015). Vegetative reproduction is preferable more than others due to its ability to resolve the problem of male bias, and only the eligible plant can be selected (Al-Obaidi et al. 2017b). To speed up the plant growth, plantations should be in warming periods of the year especially when the temperature of soil around or higher than 21 °C, with depths of 20–33 mm (Kumar et al. 2013b). Jojoba blooming takes place at the beginning of winter through March to May (Genaidy et al. 2016). At the end of the fourth year of a plantation, jojoba will produce higher economic yield (Khan et al. 2017).

Distinguishably, jojoba differs from other related oil seed shrubs such as corn, peanut and soybean in which the production of oils as the essential storage lipid, jojoba wax comprise 50% of seed dry mass (Al-Obaidi et al. 2013). Previously, jojoba oil has been recorded to have a strong potency in skin treatment and cosmetics industry; these valuable oils are vital in the manufacture of skin care moisturizers (Zięba et al. 2015). In addition to that, jojoba is utilized to fight and reduce desertification in wide areas (Sánchez et al. 2016) and also in the production of hair conditioner and curing agent for psoriasis and acne (Odoms 2012). Easily-removed lubricants anti-inflammatory efficacy (Guirguis et al. 2013). In recent years, it is used as biofuel and easily-removed lubricants (Shah et al. 2010). The shrub has powerful activity in food improvement (Kassem et al. 2011).

### 19.1.1 Medicinal and Pharmaceutical Significances of Jojoba

Local American citizens use *S. chinensis* as medical agent for cold recovery, wounds, sore throats and verruca (McKeon 2016). Insecticidal, antifungal and anti-feedant properties of jojoba have been recorded previously (Clericuzio et al. 2014). Oily extracts of jojoba are also observed to have antimicrobial action against many pathogenic microorganisms (Al-Ghamdi et al. 2019). In Sudan, a prior study indicated the antiproliferative and antimicrobial activities of jojoba oil (Elnimiri and Nimir 2011).

Jojoba extracts and milky fluids displayed functional antimicrobial activities against some pathogens such as *Escherichia coli*, *Salmonella typhimurium*, *Candida albicans* and *Clostridium perfringens* (Abu-Salem and Ibrahim 2014). Oily extracts of jojoba showed anti-inflammatory properties in rat, causing a decrease in prostaglandin rate and fluid accumulation; also alcoholic seed extract revealed antioxidant activity which in turn can keep rat liver in safe versus fumonisin B1-stimulated hepatotoxicity (Abdel-Wahhab et al. 2016). Additionally, crudely seed extracts of the shrub recorded important antimicrobial action against yeast and bacteria (Dey et al. 2014). Coats of seed combined with jojoba male and female leaves possess antibacterial and cytotoxic ability against cell lines of cancer (Hani et al. 2014). Cyclooxygenase-2, an enzyme responsible for pain and inflammation, and its value in carcinogenesis appear in high productivity of prostaglandins, preventing apoptosis; modifying pro-carcinogens into carcinogens, angiogenesis and increased pervasiveness; and modifying immune system (Wang et al. 2018). Jojoba releases cyclooxygenase inhibitor which was shown to have antitumour activity (Abdel-Mageed et al. 2016). Flavonoids also considered valuable antioxidant compounds having a beneficial role in the treatment of disturbances such as inflammation, cancer and asthma (Abdel-Mageed et al. 2014). Lipoygenase inhibitor and antioxidant isolated from jojoba is an enzyme which has importance in leukotriene synthesis, which was indexed to play a serious role in the elimination of free radical disorders.

Simmondsin and its derivatives, 4-demethylsimmondsin-2'-ferulate, simmondsin-3'-ferulate and 4,5-didemethylsimmondsin, are correlated with the antioxidant activity of jojoba (Hani et al. 2014). Stability of jojoba liquid wax and its tolerance to rancidity and oxidation (Mishra et al. 2011) reported to have stability in penicillin products; jojoba oil is the optimum liquid wax in this matter (Bilin et al. 2018). In pharmaceutical industries, Egyptian jojoba oils are preferred due to the high content of triglycerides and carboxylic acids (Al-Ghamdi et al. 2017). Mixing 30 ml of 0.5,1 N (HCL, NaOH) with 70 ml ethyl alcohol, is the most promising extraction method for the assessment of antibacterial and antioxidant activities of all handling processes especially in phytomedicines, the output is natural compounds and the remaining particles utilized to carbon activation (Akl et al. 2019).

Jojoba therapy by natural extracts may create new prospects for medicinal inventions of coriaceous wounds (Pazyar et al. 2014). Jojoba oils are suitable for all types of skin; it encourages wound healing by enhancing collagen production in tissues (Ranzato et al. 2011). Human sebaceous gland secretions contain wax esters

obtained from the redistribution of purified plant oil including omega-7 fatty acid and purified oil of jojoba due to its unparalleled chemical structure with high similarity to human sebum (Brown et al. 2016). Chemical analysis study revealed that jojoba oil own antioxidant characteristics use for repression and tackling several illnesses such as diabetes and stroke (Manoharan et al. 2016).

Alcohol derivatives of jojoba oil such as 15-tetracosenol, 13-docosenol and 11-eicosenol, possess many pharmacological properties particularly as antiviral activity; these traits make jojoba oil worthy (Sánchez et al. 2015). Moreover, they work as carrier oils valuable in hair healthiness (He et al. 2017). Micro-emulsion of jojoba oil is reported to have ability in decreasing the troublesome of Tazorac which is the ethyl ester of tazarotene acid, increasing its skin sedimentation and enhancing treatment of psoriatic illness (Nasr et al. 2017). Jojoba wax owning anti-inflammatory properties, according to that, they can eliminate neutrophil seepage as noticed by lowering myeloperoxidase efficacy and decreasing carcinoma necrosis and nitrous oxide production, it was shown that jojoba waxy compounds may be valuable armoury against psoriasis (Pazyar and Yaghoobi 2016).

Bright significance of jojoba oil is to restrain shaving wound, segmented lips, windburn and sunburn (Arafat and Basuny 2018). Antimicrobial activity of jojoba oil through mixing with hydrated lime combined with saline plays an active role in exceeding the rehabilitation of invading microorganisms *Enterococcus faecalis* and *Candida albicans* on teeth (Fayed et al. 2018). A study on callus culture of jojoba showed that the synergistic effect between 2,4-D and kinetin resulting in the production of phytochemical active compounds; in addition to that this mechanism may be used medically as the origin of antimicrobial items (Solliman et al. 2017).

When hyperglycaemia happens by insulin disturbance through diabetes, and raising of reactive oxygen species standards will lead to cellular defect, polyphenolic acid will be the strongest weapon to decrease the oxidative stress (Plummer et al. 2016). The affluence and variation in jojoba seed particles make the shrub a vigorous agent to inhibit the devastation of RINm5f beta cells encouraged by hyperglycaemia, lessening 59% of simmondsin and 69% of reactive O<sub>2</sub> species for watery extract (Belhadj et al. 2018). Jojoba volatile oils, one of the unique properties that can be used with other essential oils, can work as carriers for massage oils in aromatherapy process (Michalak 2018).

Rapid penetration of jojoba oils showed that serum non-esterified fatty acid (NEFA) levels are increased half an hour after transcutaneous donating of jojoba oil, mode of action for the raising NEFA levels attributable for increased lipolysis via patatin-like phospholipase upregulation in the liver and minimizing fatty acids runoff by fatty acid transport proteins in skin (Matsumoto et al. 2019). Jojoba oil physical and chemical characteristics close to meibomian gland excretions, used in either treatment of dry eye symptoms or for medications acceptance by meibomian tissues. Moreover, jojoba wax tears utilized to extenuate eye harassment and irritability as well as blur, jojoba wax is efficacious upon local application to permeate the lid edge until reaching gland tissues where may impact as therapeutic agent alone, or with an assistant agent (Maskin 2013).

### 19.1.2 *Industrial and Commercial Uses of Jojoba*

*S. chinensis* is a remarkable industrial plant; with attentions raised about the obtainability of perfect raw substances for several industries to depress the cost of the product, jojoba industry relies on its oil; also the remaining seed materials are important in biofuel, animal meals and cosmetics (Agarwal and Khan 2018).

Bio-lubricants are preferable more than traditional lubricants, due to valid viscosity, little emissions, less volatility and high flash properties (Pathak et al. 2019) and higher flashing point activity of shrub-related bio-lubricants obtained from the high molecular weight of neutral fats (Matiliunaite and Paulauskiene 2019). Naturally, industrialization processes require more lubricants; regrettably, the wide usage of petroleum-dependent oils contributes to ecological pollution; thus natural vegetable oils are an excellent solution for providing bio-lubricants which are more friendly to the environment (Al-Obaidi et al. 2017a), in addition to its high-performance hydropower oil applications (Bhaumik et al. 2019). Jojoba lubricants preferable more over the world in term of high tolerance to pressure and elevated temperature, consequently to high boiling point 389 °C of jojoba oils, their consistency in the cutting process is impressive (Bilin et al. 2018). Formulation mode of jojoba bio-lubricant performing by mixing it with some engine materials, increasing its specialization in term of industrial standards for 10 W oil products synergistically, resulting 238 °C flashpoint, 242.2 viscosity point and low stream point at 5 °C (Hassan et al. 2019). Mixing a small amount of jojoba oil and mineral oil showed greater friction than mineral alone, adding nano-graphene particles to 20% of jojoba oil which had increased lubrication potential than mineral oil; therefore this ratio of combining may be superior to replace mineral lubrication process (Alotaibi and Yousif 2016; Kannan and Rameshbabu 2018). The environmental analysis showed that using jojoba bio-diesel leading to restrict emissions and better engine streamline, a combination of 10% of jojoba bio-lubricant resulted in perfect records in comparison with SAE20W40 mineral oil (Gupta et al. 2020). During the last 50 years, the energy demand has been steadily growing, and the scientists show that this may increase with time, and then the number of harmful gas emissions will increase and motivate global warming (Du et al. 2018). Blending properties of jojoba wax may be developed; enhancing physio-chemical properties of wax will lead to using it as an alternative fuel source, initially by blending wax with diesel resulting in an effective tool for decreasing engine troubles related with high viscosity of jojoba methyl ester (Agarwal et al. 2020). Jojoba oil is known to be incentive converted into bio-diesel, the energy can be increased and CO<sub>2</sub> emissions will be lowered by 52% by utilizing composts as fertilizers, 50% of fossil fuel used in esterification step and all types of diesel-fuel for road cars and agriculture machines, can be replaced by jojoba bio-diesel (Sandouqa and Al-Hamamre 2019). Another study by using raw oil of jojoba when blended with petroleum-diesel leading to a noticeable reduction in hydrocarbon and nitrogen oxide emissions, associated with reverse effect with electromagnetic waves to heater walls (Al Omari et al. 2019). Jojoba meal is a valuable term in the food industry; after oilseed purification, the

remainder consists of 26–33% protein as crude, fibres, vitamins and carbohydrates (Chaudhary and Tripathi 2017). Jojoba seed can be used in frying due to high-temperature tolerance, also used to liquefy salad despite being indigestible (Krist 2020). Researchers recommend that it is useful if the farmers adding jojoba meal as a constituent of fish feeding, its ability in enhancing animal general health, improving blood system, increase resistant to invading pathogens and disease recovery (Sarhan et al. 2019).

Jojoba oil also has anticorrosion activity showed by preparation of three green rust inhibitors, through the reaction of brominated-jojoba oil with several amines, it was recorded that concentration of rusted iron decreasing, relating with rising of jojoba oil inhibitor, under chemical analysis procedure (Nasser 2017). Another significance of using jojoba oil as an antifoaming agent in the hydrocarbon industry, low amount of shrub natural oil having a good value of foam inhibition under low temperature 20 °C, heat stability of its oil also beneficial in calorimetric methods (Cevada et al. 2017; Khairi 2019). In the cosmetic industry, jojoba oil has a precious impact in main markets, and many main companies use it as raw materials (Bilin et al. 2018). In Northwestern Mexico, three ecospecies of jojoba analysed by Inter Simple Sequence Repeat (ISSR) markers revealed about 83% polymorphism over many other genotypes for usage in the cosmetic industry (Araiza-Lizarde et al. 2017).

### 19.1.3 Environmental Influence

The ability of *S. chinensis* to grow in arid and hot environment 35–48 °C will lead to acclimation with variable undesirable habitats of the world; nowadays agriculture of jojoba is wide in the United States, Australia, Peru, India and some regions of Asia, on marginal areas (Sturtevant et al. 2020). Despite the solar radiation intensity and dry conditions, jojoba has typical adaptation system; a study proved that regional environment may affect plant expression of dimorphic properties, during midday jojoba direct its leaves to the sun due to the lack of *Paraheliotropic* leaf movement (Eskander et al. 2018).

In terms of bioremediation, *S. chinensis* seeds were examined and extracted with many solvents, at all concentrations, the result showing a significant larvicidal effect on *Culex pipiens* fourth instar larvae, which considered a vector of many diseases of birds, humans and other animals. Also, LC50 of 1.905% for jojoba oils against *Spodoptera littoralis* second instar larvae invading cotton in Egypt, results indicated a decrease in pupal, larval intervals for the second instar larvae survival (EL-Sabagh et al. 2019). Cooperation between jojoba roots and endophytes, promoting rhizogenesis of the shrub, stress restriction caused by biotic, abiotic agents, activating defence mechanisms in shrub through enhancing enzymes activities of jojoba (Perez-Rosales et al. 2018). The usage of jojoba seed residues in the removal of dyes and heavy metals such as ferric ions from wastewater, these dyes are mutagenic, dangerous and poses a threat not only to human but also environment, so the

treatment of these toxicants is by adsorption potential of jojoba seeds (Al-Zoubi et al. 2020).

Globally, thousands of hectares of crops suffering from salinity, thus adding of proline to jojoba soil causing superior influence in reducing salinity and rising salt tolerance of other shrubs for the same soil in related areas (Alotaibi et al. 2019). Previous work concluded that plant-bacteria interaction is a useful pattern in reducing salinity, inoculation of *Azospirillum brasilense* Az39 and Cd strains on jojoba soil leading to reduce the deleterious effects of NaCl on jojoba root formation, increasing plant salt tolerance (Gonzalez et al. 2015).

Low conservation, drought-tolerant, prolonged-live and low-burning hazards of *S. chinensis*, so it can be utilized on highways and roads as wayside implantations and fences, as well as soil stabilizer in green straps surrounding desert towns anguished from air-particles pollution (Khan et al. 2017). In Sinai desert, Egypt, plantation of jojoba as the antidesertification plant is remarkable; S-700, S-B and S-610 are superior jojoba clones providing altitude production and may be recommended for trade plantations in arid and semi-arid areas such as Saudi Arabia and Iraq (Bakeer et al. 2017). In the same desert, jojoba cultivated as antidrought shrub due to high tolerance to water stress according to several morphological alterations such as leaf thickness increasing and leaf dimensions detracting, originally jojoba influenced by high irrigation intervals (Khattab and Amin 2018). Supporting research in transcriptional profiling after RNA sequencing had detected the genes responsible for jojoba antidrought advantage; samples were collected under normal and high water stress conditions in Saudi Arabia (Al-Dossary et al. 2020).

*S. chinensis* AA-5 was tested previously to strengthen the phytoremediation capacity of Jojoba in the aquatic system; results showed the ability to remove nickel and cadmium heavy metals (Kara et al. 2013). In India, plantation of jojoba is considered safe and environmentally friendly, leading agricultural companies which suffering from gerbils and rodents, to use protein meal fat-free of jojoba as antifeedant, according to dose-dependent, this meal has an extraordinary mortal effect on farm-destructive animals (Chaudhary and Tripathi 2017).

## 19.2 *Aloe vera*

Mentioned throughout recorded history and given a high ranking as an all-purpose herbal plant, *Aloe vera* is considered to be one of the most potent *Aloe* species, with commercial importance and popularity in research (Kumar et al. 2017a). *A. vera* is well-known for its considerable medicinal properties; it is one of the richest natural sources of health for human beings. Various parts of the plant contain approximately 75 nutrients (Radha and Laxmipriya 2015), as well as tens of active compounds including amino acids, vitamins, carbohydrate, minerals, saponins, anthraquinones, lignin and salicylic acid (Misir et al. 2014). Historical findings regarding *A. vera* date back to hundreds of years B.C. in old Egypt and Mesopotamia (Manvitha and Bidya 2014). Old Egyptians, Arabs, Romans and Indians also recognized the heal-

ing properties of this plant, especially that related to skin and hair treatment (Joseph and Raj 2010). *A. barbadensis* Miller, commonly referred to as *A. vera*, is one of few hundred species of *Aloe* belonging to family Liliaceae that is native to Arabian peninsula but have been found also in dry tropical and subtropical areas (Kumar et al. 2020).

Complex carbohydrates obtained from natural sources such as plants have shown diverse biological activities such as wound healing, enhancement of the reticuloendothelial system, stimulation of the immune system, treatment of tumours and effects on the haematopoietic system (Talmadge et al. 2004). Generally, *A. vera* has many potential uses both for humans and animals such as gel, latex and the whole leaf extract, whose biological ingredients may act alone or in synergy (Christaki and Florou-Paneri 2010). *A. vera* also well-known for its anti-inflammatory, antioxidant, antidiabetic, relief of sunburn, immune booster, antiageing and anticancer properties (Langmead et al. 2004). *A. vera* is a perennial shrub with the ability to store water in the leaves to survive during the dry season/condition. The thick fleshy leaves of *A. vera* plants contain not only cell wall carbohydrates such as cellulose but also carbohydrates such as acetylated mannans (Ni and Tizard 2004). *A. vera* leaves have a long history as a therapeutic plant with diverse healing applications. Many biological activities were linked to the presence of polysaccharides in the leaves gel (Hamman 2008). But those *A. vera* properties could also be linked to volatile compounds, cellulose, lignin, pectin, hemicellulose phenolic compounds, minerals and vitamins (Heś et al. 2019).

### 19.2.1 Medicinal and Pharmaceutical Applications

The plant *A. vera* is used in ayurvedic, homoeopathic and allopathic streams of medicine, and not an only tribal community but also most of the people for food and medicine (Sahu et al. 2013). The chemistry of the plant has revealed tens of different compounds which include many medicinal and pharmaceutical with potential clinical applications (Nazeam et al. 2020). *A. vera* is anthelmintic (Mwale and Masika 2015), laxative (Guo and Mei 2016), aperients, carminative (Thompson 2008), deobstruent, depurative, diuretic, stomachic and emmenagogue (Chinnadurai et al. 2018). Pharmacologically, it is considered an immunity booster with detoxifying properties; it is also recommended for supporting treatment with antibiotics to eliminate drug-induced gastritis and other adverse effects. It has been reported that the polysaccharides in *A. vera* gel have potential therapeutic properties, antioxidant, wound healing, antibacterial, antiviral, antifungal, antidiabetic and antineoplastic activities (Kaushik et al. 2014; Kumar et al. 2019).

*A. vera* has been reported to have antifungal activity, hypoglycaemic activity, anti-inflammatory, anticancer, immunomodulatory, gastroprotective and antihepatotoxic properties (Hamman 2008). It is good for conjunctivitis, dysentery, kidney pains sprains, stomatitis, sore throat, skin burns, scalds, scrapes, sunburns, wounds pimples, acne, cuts dandruff, hair fall and baldness (Alapati and Sulthana 2015).

Dried juice of leaves has the potential to be used in dysmenorrhoea and diseases of the liver. It is used in jaundice due to viral hepatitis and in spleen disorders. Gel topically is emollient, anti-inflammatory and antimicrobial used for wound healing and sunburn. *A. vera* detoxifies the body and is considered as the best colon cleanser. It prevents constipation, controls diabetes and clears acne and skin allergies and dark spots (Verma et al. 2013).

*A. vera* also exhibits skin protective properties, and it has been used in this role throughout history since ancient times (Qadir 2009). It has been demonstrated that *A. vera* and its active compounds have effective therapeutic properties on several chronic skin diseases such as psoriasis and eczema (Khan et al. 2016). *A. vera* gel can be used for the treatment of pimples and protection of the skin from ageing, and it is thus used in the cosmetics industries providing moisturizing effects (Sahu et al. 2013). The leaf gel materials of *A. vera* and few other *Aloe* species was shown an in vivo study shown the ability to rehydrate skin (Fox et al. 2014). *A. vera* juice showed promising repair properties for UV-induced human hair damage (Daud and Kulkarni 2011). Also study on rats indicated that extract of *A. vera* gel can promote hair growth (Pamudji et al. 2015).

The results of the recent study depicted that *A. vera* gel extract has significant anti-inflammatory property particularly in an increased dose of gel extract (Afzal et al. 2020). The ability of healing wounds has been reported in many earlier studies (Rahmani et al. 2014; Keorochana et al. 2015; Oryan et al. 2016; Hormozi et al. 2017; Ranjbar and Yousefi 2018; Oryan et al. 2019; Abdel-Mohsen et al. 2020b; Zhang et al. 2020). In a comparison study of *A. vera* gel dressing with a simple dressing on the wound immediately after caesarean section. In the *A. vera*-treated group, wound healing and pain reduced faster than the control group in the first 24 hours (Molazem et al. 2015). In another study, wounds of patients were treated with *A. vera* gel two times a day in combination with current treatments, and the control group only used conventional treatments, while the *A. vera*-treated patients wound healing occurred in about a month, while in the control group it took 2 months (Avijgan et al. 2016). *A. vera*, together with other two *Aloe* species, have shown the ability to speed up the healing of wounds in keratinocytes with negligible toxicity on normal human keratinocyte cells (Fox et al. 2017). *A. vera* gel used to treat nulliparous episiotomy patients, the pain reduced after 10 days of treatment (Sabzaligol et al. 2014). The dental and oral disease also reported being treated by *A. vera* gel (Nair et al. 2016).

Acetone extract from *A. vera* shown growth inhibition effect on pathogenic bacterial species *Staphylococcus aureus* and *Salmonella enterica* (Adzitey et al. 2019). The results showed *A. vera* inner gel expresses antibacterial properties against *Helicobacter pylori* and therefore, in combination with antibiotics, could represent a novel strategy for the treatment of the infection of *H. pylori*, especially in cases of multiresistant (Cellini et al. 2014). The orally administered *A. vera* supplemented probiotic lassi was found to prevent *Shigella dysenteriae*-induced infection (Hussain et al. 2017).

Aqueous extract of *A. vera* shows hepatoprotective activity against carbon tetrachloride CCl<sub>4</sub>-induced hepatotoxicity in rats (Salama et al. 2016). While ethanolic

extract of *A. vera* leaves shows renoprotective action against gentamicin-induced nephrotoxicity in rats (Virani et al. 2016). On the other hand, *A. vera* gel could suppress the mRNA expression of lipogenic genes in mice by modulating various pharmacological pathways (Kumar et al. 2013a). *A. vera*-positive effect on the treatment of diabetes was observed with the intervention of its supplementation significant reduction which was observed in blood glucose, lipid profile and blood pressure of the diabetic patients (Choudhary et al. 2014). A clinical study has shown the hyperglycaemic activity of *A. vera* gel patients with type 2 diabetes (Pothuraju et al. 2016).

In vitro and in vivo antioxidant activities of *A. vera* gel constituents have been reported (Kang et al. 2014). Numerous studies have shown that different compounds in *A. vera* leaves have anticancer properties by modulating the growth of various cancers (Ahmet et al. 2016). Another study also demonstrated that aloe-emodin caused cell apoptosis in colon cancer cells (Suboj et al. 2012). An immunomodulatory study on rats showed that *A. vera* gel extract is taken orally at a dose of 200 and 400 mg/kg exhibiting significant phagocytic activity as compared with aspirin (Bhalsinge et al. 2018). *A. vera* extract revealed nerve protective activity by reducing the mitochondrial damage in the rat brain (Wang et al. 2010) and antiparkinson and antioxidant activities in mice (Bagewadi and Rathor 2014).

A herbal product used with an aqueous extract of *A. vera* showed antiviral activity against influenza A and influenza B viruses (Glatthaar-Saalmüller et al. 2015). *A. vera* gruel plays a significant role in the adjuvant therapy of HIV infection (Olatunya et al. 2012). In summary, compounds found in *A. vera* exhibited antioxidant activities in vitro and in vivo, suggesting that *A. vera* could be beneficial in combating diseases related to oxidation stress in the body such as cancer, diabetes as well as cardiovascular disease (Yang et al. 2017).

### 19.2.2 *The Industrial Importance of A. vera*

*A. vera* gel enables the plant to hold water for a long time and has soothing effects as well. So, *A. vera* has found an extensive application in cosmetic and skincare industries, such as cleansers, moisturizers, deodorants, sun lotions, toothpaste and shaving creams (Benítez et al. 2015). The use of *A. vera* gel extract in the preparation of functional foods started 40 years ago in North America and Europe (Maan et al. 2018). Since then its applications have been expanded to the functional and nutraceutical foods especially for the preparation of health drinks, also used as a flavouring component and preservative (Park and Jo 2006). The addition of basil seed mucilage to *A. vera* gel or their application as an edible coating could be a promising approach to maintain postharvest quality and control physiological process of apricot fruits during cold storage (Nourozi and Sayyari 2020).

Also chitosan-*A. vera* combination can be used to extend the storage life of mango fruit (Shah and Hashmi 2020). Edible films based on potato starch, chitosan and *A. vera* gel (AV) as modifiers were evaluated towards their potential application in food or cosmetics industry. All the samples with *A. vera* gain the increase resis-

tance to microbial action (Bajer et al. 2020). Development of water-resistant carboxymethyl cellulose-coly vinyl alcohol - *A. vera* packaging film; it delayed lipid peroxidation and inhibited the growth of bacteria in the minced chicken meat (Kanatt and Makwana 2020).

Green synthesis of cubic  $\text{In}_2\text{O}_3$  nanoparticles (NPs) (5–50 nm) was reported using indium acetylacetonate and *A. vera* plant extract solution (Dinesh et al. 2015). Highly stable and spherical ZnONPs using *A. vera* extract have also been synthesized (Abdullaeva 2017).

The most promising materials for wounds and burns dressing are still based on natural polymers such as polysaccharides (alginates, chitin, chitosan, heparin, chondroitin), proteoglycans and proteins (collagen, gelatin, fibrin, keratin, silk fibroin, eggshell membrane) (Mogoşanu and Grumezescu 2014). Recently reports illustrated the importance of *A. vera* in wound dressing manufacturing (Abdel-Mohsen et al. 2020a; Dadashzadeh et al. 2020). Preparation of solid lipid nanoparticles modified with *A. vera* for antiviral drug delivery applications showed promising result (Joshy et al. 2016). The mucilaginous nature of *A. vera* gel also helps it to serve as a protective barrier between skin and beard in shaving creams (Lad and Murthy 2013). The *A. vera* fibre-reinforced biocomposites have a huge potential to be used in applications such as automobile interior trims, consumer electronics like mobile phone body parts as well as non-toxic toys for children (Chaitanya and Singh 2018).

### 19.2.3 Environmental Impact

Recently, *A. vera* and its by-products have attracted attention for employment in environmental applications; this plant grows readily in hot and dry climates. It has been reported that different agro-climatic conditions have effects on phytochemical diversity and antioxidant potential of *A. vera* plant (Rahman et al. 2017). Antioxidant activity was higher in *A. vera* plants grown in India concluding that more metabolites are produced in plants under low-temperature stress conditions (Kumar et al. 2017b). Investigation shows that the *A. vera* is effective and inexpensive adsorbent for the removal of Pb, Cd, Ni, Cu, Cr (III) and (VI) from contaminated soil by heavy metals (Shokri et al. 2016). The surface properties of activated carbon from *A. vera* leaf shells were modified by sulfuric acid *A. vera*-acid activated carbon (AV-AAC) and then used as a novel adsorbent to remove para-chlorophenol (p-CP) and methylene blue (MB) from aqueous solutions (Zeydouni et al. 2020). An effective, low-cost, rapid adsorption rate and high adsorption capacity adsorbent synthesized from waste *A. vera* leaves, which has been used to remove the maximum concentration of Cr (VI) from the synthetic solution (Prajapati et al. 2020). *A. vera* waste biomass-based sorbents, as well as modified counterparts, are used for the removal of heavy metals, dyes and other pollutants from aqueous media (Giannakoudakis et al. 2018). The emergence of environmental issues such as air pollution has greatly required the need for cheap, adaptable and eco-friendly remediation systems for purifying

the environment. *A. vera* emits oxygen at night; it is almost a “no-maintenance” plant and caters to a lot of beauty benefits too (Kulkarni and Zambare 2018).

The pyrolysis treatment of *A. vera* leaf is cost-effective, friendly to the environment and profitable, with which the highest performance in biochar and condensable fuel is obtained with lower gas production (Strubinger et al. 2017). Green composites (biocomposites) comprising lignocellulosic fibres are low-cost sustainable materials having huge potential to replace petroleum-derived commodity and engineering plastics (lignocellulosic). *A. vera* fibres exhibited eco-friendly fibre to limit the environmental hazards of conventionally used chemical fibre (Chaitanya and Singh 2016, 2018; Ramesh et al. 2020).

### 19.3 *Moringa oleifera*

Highly content of minerals and vitamins as well as food diversity in *Moringa oleifera* Lam has been led scientists to name it the miracle tree it is a type of native medicinal grass which is common in the equatorial and subequatorial areas (Abdull Razis et al. 2014). Moringa has seven-time vitamin C more than oranges, ten-time vitamin A more than carrots (Gopalakrishnan et al. 2016), 17-time calcium more than milk, nine-time protein more than yoghurt, 15-time potassium more than bananas and 25-time iron more than spinach (Rockwood et al. 2013). As the most economic prominent species among others belong to the family Moringaceae, there are other names for this shrub as drumstick or horseradish, Mulangay, Benzolive and Mlonge; the name drumstick came from the shape of the tote bag or pendulous, like the tender and turned stick used for flogging the drum. Perhaps the name radish came from the pendant, the slim and tender shape of the unripe fruits of the tree so much as the siliqua of the radish (Abdull Razis et al. 2014; Sandeep et al. 2019). India is one of the bigger producers of moringa, a yearly harvest of about 2.2 million tonnes (Raja et al. 2016).

The vegetative parts of *M. oleifera* consist of stems, twigs, compound leaves, flowers, fruity pods as well as the seeds; all parts are traditionally utilized for various purposes; leaves are usually the most utilized in the world (Mallenakuppe et al. 2019). Moringa is rapid growing and retains green leaves (Chukwuebuka 2015); the leaves have two or three leaflets with the latter being the most common where it takes spiral shape on the branch (Agyepong 2009). The flower is aromatic and androgynous, with five yellowed-white petals and contain different veins. In more fixed seasonal heat and with stable rainfall, bloom can occur two times or even along the year (Alhakmani et al. 2013).

At the maturity, the tree become grown and divide vertically from the three corners along with the pods; then the blackish-brown seeds are released; adult *Moringa* tree of 15–20 feet high can produce thousands of seed pods and therefore produce uncounted seeds every year (Zaku et al. 2015).

*M. oleifera* proliferates by seed plantation, seedling growing and parts of the stem. Seed plantation is favoured, seeds often sow at the deepness of 2 cm, deeper

than that may cause a decrease in the growth rate (Aslam et al. 2019). Moringa can live a broad extent of soil situation, but predominating choose neutral acidic soil where it takes to grow 5–12 days after planting (Mallenakuppe et al. 2015; Raja et al. 2016). *M. oleifera* is considered as a worthy food resource; it is utilized in the food industry as well as in the development of stable feed in animal feeding which has been palliated (Sahay et al. 2017). Some researchers have highlighted the use of *M. oleifera* as supplement therapy or for use in the prevention of disease (Mohammed et al. 2012; Gadzirayi et al. 2012; Alegbeleye 2018). *M. oleifera* extracts are often added with canned foods to preserve their chemical and physical properties, as well as increase the shelf life of the product (Gull et al. 2016). Different parts of the *M. oleifera* shrub have shown antimicrobial activities (Zaffer et al. 2014) and anti-oxidant and antidiabetic properties (Vargas-Sánchez et al. 2019). *M. oleifera* has been used to treat over 300 diseases in India and Africa continent (Gopalakrishnan et al. 2016).

### 19.3.1 Medicinal Uses and Pharmaceutical Applications

Considerably all parts of *M. oleifera* have potential use in treating different infections and inflammatory diseases relating to cardiac, gastrointestinal, haematologic and tumour maladies (Abdull Razis et al. 2014). *M. oleifera* leaves provide important sources for antioxidant, group of different vitamins, metals and amino acids and a wide range of protein sources (Saini et al. 2016). Additionally, anticancer activity of the plant is relating to its antiproliferative action; in addition to that cancer cells can be targeted by reactive O<sub>2</sub> species from *M. oleifera* (Tiloke et al. 2013; Reetu et al. 2020). Phenolic compounds such as Robigenin and Flavin meletin indicated by HPLC having a potential antiproliferative action against apoptosis, thus indicating that extracts of *M. oleifera* leaves have potential of cancer prevention and sometimes may be used as cure site for cancer (Sreelatha et al. 2011). Nectar production by shrub flower may have anti-inflammatory action (Gopalakrishnan et al. 2016). Some cases of skin infections, some conditions of anaemia and gastrointestinal ulcers may be treated with selectively wood extracts medications termed alkaloid spirochim (Vergara-Jimenez et al. 2017).

Depending on the massive medicinal qualifications of *M. oleifera*, leaf extracts from this plant possess antioxidant and phytochemical properties (Yaméogo et al. 2011). Moreover, medical co-agents contributing to decreasing cholesterol level enhance the immune system, antiulcer, toxin illuminating agent, diuresis and treating of spasticity also observed (Okiki et al. 2015). *M. oleifera* has inhibition effect against microbial pathogenicity combined with recently organized studies indicating that aqueous extract of the plant showed a noticeable effect against *Bacillus*, *S. aureus* and *Escherichia coli* with scheduled doses (Saadabi and Zaid 2011). This shrub has great antifungal properties versus *Aspergillus niger* and slightly lower with *Aspergillus nidulans* and *Aspergillus terreus* (Kekuda et al. 2010). Leaf extracts in ethyl alcohol of this plant also had an inhibition effect indicated against the earth-

worm *Pheretima posthuma* (Rastogi et al. 2009). In a comparison study between moringa seed extract and nonsteroidal anti-inflammatory aspirin, the study showed the high anti-inflammatory effect of seed extracts considerably reduced inflammation signals and increased detoxification in lipopolysaccharide-induced bone marrow macrophages (Jaja-Chimedza et al. 2017). The shining side of pharmaceutical applications for *M. oleifera* is wound healing (Tang et al. 2017; Li et al. 2020). Mixing an equal percentage of calcium-alginate acid-polyethylene glycol ethyl ether methacrylate (PEGMA) with *M. oleifera* and *Aloe vera* increase cell viability after few days, in comparison with scaffolds free of shrub extracts showing that two plant extracts combination with calcium-alginate acid-PEGMA possessing considerable chance in wound healing medications (Rubio-Elizalde et al. 2019). These equal amount of both two plant extracts combined with calcium-alginate acid-PEGMA highly affects human skin cells to proliferate rapidly after 7–10 days due to existence of bioactive compounds in the gel of both *M. oleifera* and *A. vera* (Skotti et al. 2014). Recent studies signalize utilizing of naturalistic nontoxic compounds which rely on substitution of chemical compounds with plant natural products, for instance, in slabs, moisturizer, suspension and salve (van Wyk and Wink 2015; Hwang and Lyga 2017; Young 2019). *M. oleifera* gum production is a real pharmaceutical example of synthetic cream polymers used in wound healing or injuries events prescribed by pharmacologists (Uphadek et al. 2018). Diabetes considered to be one of the most traditional illnesses is included in the applications of *M. oleifera* pharmacology leaves of moringa used to treat type 1 and type 2 of diabetes (Taweerutchana et al. 2017). Once a prior investigation for utilizing the hydrous extract of leaves to recover streptozotocin of type 1 and insulin hormone of type 2 with rat laboratory animals (Cerf 2013).

As shown previously, all parts of the shrub extracts are of medical value and also in terms of the bark of *M. oleifera* stem can be used in different properties in preventing pain in addition to elimination irritant reactions, thus providing results using traditionally in inflammatory cases (Kumbhare and Sivakumar 2011). Petroleum naphtha, ethyl ethanoate and methanolic leaf extracts of *M. oleifera* were discussed in many published papers to have an analgesic effect (Manaheji et al. 2011; Dubey et al. 2013; Al-Abri et al. 2018). Antipyretic characteristic has also been examined practically with baker's yeast; therefore according to previous results, methanolic extracts showed an elevated level of effectiveness (Reddy and Kuber 2017). Natural compounds of *M. oleifera* may be developed using amelioration of anti-inflammatory medications relating to chronic diseases (Muangnoi et al. 2012). Substantially phytochemical ingredients of *M. oleifera* such as amphipathic glycosides, tannic acid, phenolics, flavonoids, limonene and alkaloid organic compounds; the presence of these substances with diverse shape among the same genus will lead to broad pharmacological uses with wide circumstances (Rani et al. 2018). Polyphenolic antioxidant natural components can lower the oxidation level in cells by free radicals (Vergara-Jimenez et al. 2017). In return to the high ratio of *M. oleifera* polyphenols combined with studies of methanol extraction of leaf materials such as sophoretin, meletin, 3-caffeoylquinic acid, 3-caffeoylquinic acid, sophorin and condensed tannin, all contributing to decreasing tissue damage (Gopalakrishnan

et al. 2016). In addition to a group of leaf extracted polyphenols such as  $C_{16}H_{12}O_5$  flavon, Apigenin-8-C-glucoside flavone, ortho-coumaric acid 2-hydroxycinnamic polyphenolic acid,  $\beta$ -(4-hydroxyphenyl) acrylic polyphenolic acid and vanillate indicated to have anticarcinogen activity (Joshi and Mehta 2010). Furthermore, with the pharmaceutical benefits of leaves active compounds, beta-carotenoids, alpha-Tocopherol and amphipathic glycosides having pain-reducing conducts and some alleviating properties (Tejas et al. 2012). Group of polyphenolic extracts and pharmaceutical applications also is revealed in stem bark and root (Maurya and Singh 2014). *M. oleifera* leaf extracts show in vivo ability to modulate metabolic disorder features (Irfan et al. 2020) and adjust adiponectin besides inhibiting adipogenesis in 3 T3-L1 adipocytes cells (Muni Swamy et al. 2020). Additionally, histopathological studies proved that *M. oleifera* minimizes cirrhosis of the liver (Hamza 2010). Extraction experiment of seed protein interacts with sodium lauryl sulphate was reported that protein had important antiseptic attitude, related protein is with integrated sites with sodium lauryl sulphate and markup protein-lauryl sulphate component (Bhaskar et al. 2013). Oily extracts of *M. oleifera* can be used as an aromatherapy machine and skin softener with good stability on the skin and moisturizing agent (George et al. 2018). Ethanolic extracts of shuck have a reliable hypotensive action at 0.03 gm/kg. isolation of  $ROC(=S)NR_2$  and isothiocyanates from plant leaves, assisted by production of O-ethyl-four-[( $\alpha$  -l-rhamnosy loxy)-benzyl] carbamic acid,  $\beta$ -sitosterol and others showing elevated hypotensive activity (Biswas et al. 2012).

### 19.3.2 The Industrial Importance of *Moringa oleifera*

There are more than 90 chemical compounds in *M. oleifera* of high nutritional value, inclusive of carbohydrates, proteins, fats and feeding fibres; protein is the most considerable in the part of plant among sundry nourishment, forming about 25% of arid weight (Anwar et al. 2007). *M. oleifera* is utilized in the tropics as a feeding resource to process the lack of nutrition, especially in newborns (Brilhante et al. 2017). *M. oleifera* seeds can be applied as physical treatment of water in civil and rustic regions, lowering of microorganism loading and hold off parasitic worms (Mangale Sapana et al. 2012). *M. oleifera* utilized to decrease 90% of turbidness and colour of polluted water; *M. oleifera* seeds were frugal and more active than  $Al_2(SO_4)_3$  in decreasing the turbidness of polluted water with 95% efficiency compared to 80% of  $Al_2(SO_4)$  (Gámez et al. 2015).

Also, this plant has been used to limit the spread of some harmful species of insects (De Oliveira et al. 2011). *M. oleifera* has insecticide, larvicide and ovide action versus the transports of *Anopheles stephensi* and *Aedes aegypti* (Prabhu et al. 2011). The larvicide action of proteins, such the water-dissoluble *M. oleifera* lectin acquired from seeds, has been versus organophosphate-reluctant phase four *A. aegypti* maggot (Agra-Neto et al. 2014).

The cultivation of aquatic plants for food in developed countries considered a public effort, to decrease ecological harm caused by contaminants. To reduce the use of chemicals and antibiotics for water treating, *M. oleifera* could acts as an alternate (Adesina and Omitoyin 2011). Suspensions acquired from *M. oleifera* shrivelled seeds decrease organic compounds and turbidness, on account of the efficiency of the seed extract, which remove acids of humus from water; together, these seeds encourage deposition and minimize bacterial loading in polluted water (Ferreira et al. 2011). The germicide possibility of *M. oleifera* against fungi and bacteria, return to a normal state from water animal farming merit interest, since these microbial considered a major cause of economic losses in the animal and agriculture field, besides, health troubles (Brilhante et al. 2017).

Furthermore, besides the repressing effects of *M. oleifera* on various microorganisms, it has been notified that raw extracts of leaves and seeds also prevent an enzyme that breaks down proteins and peptides of microorganism. It is acting as a muscular degenerating of fish and prawn during storage (Bijina et al. 2011). Moringa oil can be a perfect thermic, oxidative and cooking stabilization (Ogunsina et al. 2014).

A group of scholars highlighted the importance of mixing of *M. oleifera* seeds powder with wheat powder for cake products, raising the protein ratio approximately from 13% to 23%, as well as the ratio of fibres, and Fe, Zn, Ca, fats and dust also increased (Dachana et al. 2010). *M. oleifera* oil contribution as biofuel also been reported (Chinma et al. 2014).

### 19.3.3 Environmental Impact

*M. oleifera* is a type of equatorial multi-function shrub which is adapted to a semi-dry environment (Noulèkoun et al. 2018). *M. oleifera* utilized in water treating especially seeds and leaves. They have no noticeable secondary impact and are safe and decomposed by bacteria or other living organisms (Eman et al. 2014). *M. oleifera* considered a positive polymer that has several ionizable groups, which have shown to be efficient in water treating as a replacement for aluminium sulphate (Araújo et al. 2013).

*M. oleifera* is considered God's gift to some countries, especially in Asia and Africa (Mahmood et al. 2010). One of the several functions of *M. oleifera* shrub being able to contribute in the elimination of heavy minerals from water. *M. oleifera* removed most of the iron, 98% copper and cadmium (Shan et al. 2017). Fungus contamination is causing several diseases that infect plants which cause remarkable losses due to the reduction of yield (Labandeira and Prevec 2014). The aggressiveness of fungal diseases is related to toxic and dangerous impacts on the environment treated usually using chemicals (Yadav et al. 2013). *M. oleifera* proteins revealed an antifungal impact in vitro (Lacerda et al. 2014). *M. oleifera* Chitin Binding Protein

(MOCBP) is a stable glycoprotein efficiency in extremely high heat and pH (Batista et al. 2014). MOCBP3 is having wide activity versus some fungi diseases as *Fusarium oxysporum* and *Colletotrichum* spp. (Gifoni et al. 2012). *M. oleifera* seeds play a significant role in reducing pollution of palm oil waste that contains many organic and inorganic substances (del Real-Olvera et al. 2016). The oils extracted from moringa seeds have shown their effectiveness as a healthy natural coagulant for treatment of liquid waste (Othman et al. 2011). Moringa seeds worked as a good fertilizer for maize farms by improving and diversifying the solid nutrients (Emmanuel et al. 2011).

Agronomical investigations are based on the use of genetically engineered *M. oleifera* seeds to fertilize maize, resulting in refinement of soil nutritional contents. *M. oleifera* leaf extracts were exercised in curing the land polluted by crude oil, repairing processes for soil to prepare it for agriculture (Abd El-Hack et al. 2018). Hydrocarbon declination rate can be monitored and stimulated using moringa oil (Ukpaka 2016). Moringa is an exciting tree in extenuating climate counter changes, which are a real threat for a long time in countries in the Arabic region like Saudi Arabia (Robiansyah et al. 2014). *M. oleifera* cultivated widely as a forest shrub which plays an important role in reducing the temperature, aerial CO<sub>2</sub> concentration and sedimentation (Mridha 2015). The plant has high CO<sub>2</sub> absorption rate which is about 20 times more than other shrubs; the ability to store carbon makes the plant as a good potential shrub to reduce carbon footprint (Daba 2016). *M. oleifera* leaf extract is considered a natural shrub growth improver, not only enhancing plant regeneration and mass production but also encouraging bearing under stress events (Yasmeen et al. 2012). Leaf extracts are considered as a tool to overcome injuries affecting maize and increase productivity rates of genetically engineered maize seeds at minimum temperatures (Afzal et al. 2012). Leaf extracts of *M. oleifera* play a vital role as antidrought in wheat farms (Yasmeen et al. 2013).

In Asia, particularly in Saudi Arabia harsh and dry circumstances leading cultivars to farm large areas of *M. oleifera*, as a desertification-reducing agent (Mridha 2015). A similar scenario applied in African regions such as southern Ethiopia (Lemma and Mohammed 2016). Also, a study in Sudan showed that *M. oleifera* can grow under the little amount of water with no rains up to 1 month, due to the high nutritional value especially with proteins, K, Fe and Ca, versus *Moringa peregrina* which has few proteins and metals (Ali et al. 2015).

Industry in some countries like Australia relies on *M. oleifera* as a source of biodiesel production (Omonhinmin et al. 2020) to meet emission requirements. Despite low level of performance and high NO<sub>x</sub> releasing versus fossil fuels, biofuel has decreased emissions of hydrocarbon, carbon oxide and carbon dioxide in contrast to fossil fuel (Azad et al. 2015). Biodegradable and coagulation properties, numerous sources, leading to use *M. oleifera* taking off chemical O<sub>2</sub> demand and overall dissolved solids in local landfill wastes, attributing that valuable and frugal alternative over another classical method (Sivakumar 2013).

## 19.4 *Acacia*

Genus *Acacia* has a hard history in the world; it is classified as large trees and bushes. Some *Acacia* sorts are important, while others saw them as harmful plants (Rahman et al. 2019). Nourishment instability, lack and poor diet considered an issue worrying many countries around the world, particularly in drier regions. One of the most important reasons behind food deficiency is the increment in desertification and changing climatic conditions which lead to the lack of interest in some important wild species (Tasisa and Nemomissa 2019). *Acacia* is one of the shrubs that lives in the drier regions on earth, as it represents the largest part of the arid regions of the Middle East and Africa (Winters et al. 2018). *Acacia* has over 1000 different species distributed worldwide around the arid and semi-arid areas (Lake 2015). *Acacias* also considered native to equatorial and subequatorial zones, in particular Australia where they are called wattles (Khan and Sahito 2013). They are also known as mimosa and Arabic gum (*Acacia senegal*) (Choudhary et al. 2020).

*Acacias'* special leaf takes the shape of small split leaflets that give the leafstalk a plumy or fernlike look. In most Australian and Pacific Ocean species, the leaflets are repressed or absent completely; a petiole may be perpendicularly coordinated and carry forks or severely turned needles at their bas,, these are familiar as phyllodes, which are a winged leaf stalk that functions as a leaf (Maiti et al. 2016).

The flowers possess five tiny petals, roughly unobserved by the tall of the male fertilizing organ of a bloom, and are coordinated in dense groups or cylinder mass; they are xanthous or pale yellow coloured in various species, milky in some or lilacs such as *Acacia purpureopetala* or red such as *Acacia leprosa* (Ghouila et al. 2012; Gleed and Franklin 2018). *Acacia* flower can be featured from the flower of genus *Albizia*, by their male fertilizing organs (stamens), which are not connected at the basis. Also, different from mimosa flowers, *Acacia* possesses more than ten stamens (Prenner 2011).

*Acacia* seeds are distributed generally by being thrown away from the legume when it crackles, commonly under the impact of the sun. In some time the grains may stay suspended in the air by a filamentous stalk from the unfold legume, the chromatic funicle and aril effective as a substance that attracts bird (Abdelbasit et al. 2014). Most of *Acacia* species are important economically (Nigussie et al. 2020). The adhesive substance of *Acacia* especially *A. senegal* produces Arabic gum, a substance used in glue, as a medicinal drug, pontiff, desserts and other products (Nasir et al. 2012). A few types of *Acacia* include alkaloids which affect the mind, and some include potassium fluoroacetate, a rodent venom (Gonzales and Tolentino 2014).

### 19.4.1 Medicinal Uses and Pharmaceutical Applications

Medicinal plants made about 70–80% of world people plantation fundamentally in the developing countries, it is usually utilized for major health care, healthier life-style combining the ability to cure some disease with the minim side effect. Various part of the plant has different various biologically active compounds and diverse pharmacologic behaviour (Carvalho et al. 2014). *Acacia* species is one of the wealthiest biological resources, which include flavonoids, morphine, quinine, phenolic resins, saponins, carbohydrate and other organic compounds (Jelassi et al. 2016). Several parts of *Acacia* have various phytochemical compositions and various pharmacological activities (Amadou et al. 2020). Bark extracts of *Acacia catechu* had a role in treating skin pain, scarring, mouth ulcers and bronchitis (Sunil et al. 2019a). Also showed good efficacy in the possibility of using it as a catalyst for the immune system (Sunil et al. 2019b).

It has been observed that the ethanol *Acacia* extracts play a major role in wound healing, especially plant's bark because of the high content of flavonoids and alkalis (Suriyamoorthy et al. 2014). Boiling pods of *Acacia* is useful in the diseases of both urinary and genital organ and stops early ejaculation (Castillo-Mitre et al. 2017). Also, pods are utilized in aired cough (Farzana and Tharique 2014). The pods and leaf extracts are utilized for body revitalize (Dasgupta and Roy 2010). *Acacia nilotica* is used as contractile, bleeding stops, and emollient (Akbar 2020).

The fruits of *Acacia* tree are beneficial in treating infection of the intestines, diarrhoea and diabetes (Semenya and Maroyi 2012). A study estimated extracts of *Acacia farnesiana* for diabetes treatment in mice, showing that aqueous extract safely lowered glucose grade in the blood (Akbar 2020). Root's ash reported as an agent that can help in stopping diarrhoea and decrease uric acid in the urine (Das et al. 2015). Beneficial in wounding healing and helpful in burning (Iftikhar et al. 2010). Different plants parts are utilized to strengthen hair relieve ear pain and treat cholera, purge and contagious diseases (Wuthi-udomlert and Vallisuta 2011). Other studies evaluated the slough healing activity of *Acacia farnesiana* methanol leaf extracts against ulcer-motivated sample in rats. Outcomes offered the methanol extracts decreased the ulcer indicator contrast to monitoring ranitidine (Dwarakanath et al. 2013). Also demonstrated that *Acacia auriculiformis* extracts act to inhibit acetylcholine esterase and in turn enhance memory (Sharma et al. 2014a). It has been reported that the *Acacia* plant extracts had a more positive effect than a placebo gel on mouth infections, especially gingival and teeth broach (Rajvaidhya et al. 2012). In in vitro study, on Swiss albino mice, *Acacia* gum gave faster-wound renewal; also it can maintain proper moisture level at wounding surface (Parwani et al. 2019). A mixture of *Acacia* gum-sodium alginate gel with low concentrations of ZnONPs used to treat wounds and limited the growth of some pathogens (Raguvaran et al. 2017). In another study, Arabic gum was used to decrease C-reactive protein levels, which can be used as natural fibres for treatment Sickle cell disease (SCD) patients (Kaddam and Kaddam 2020). In vivo research shows that in 74 patients having haemoglobin SS, *Acacia* gum reduced transaminase and

bilirubin level in the blood, without affecting aspartame about renal function (Kaddam et al. 2019). *A. nilotica* is an important attractive appearance medical plant; it is a source of many active compounds which can be used for medicine expansion with a greater possibility of prosperity, where flavonoids and alkalis form a large percentage of the plant extract with anti-inflammatory and antioxidative properties (Rather and Mohammad 2015).

*A. nilotica* showed high content of alkali lignin, which acts as an antioxidant (Barapatre et al. 2015). Unpurified root extracts of *A. nilotica* reveal notable effect against a *Plasmodium berghei* in mice, due to its high content of terpenes, diterpenes, sesquiterpenes and derivatives of gallic acid such as tannins (Jigam et al. 2010).

*Acacia polyacantha* methanolic extracts revealed the highest antioxidant properties compared to extraction using acetone (Mohammedlnour et al. 2017). It has been observed that there is a correlation between the contents of phenolic compound and antioxidant activity in *Acacia mearnsii* (Missio et al. 2017). Extract of *A. nilotica* seeds shows the ability to lower arterial blood pressure and supplies guide of antihypertensive effectiveness (Malviya et al. 2011).

Safari and his group explained the water leaf extracts of *A. nilotica* have antinociceptive and anti-inflammatory effects, also showing the ability to reduce fever in albino mice (Safari et al. 2016). These properties attributed to the existence of compounds as alkaloid, phenolic acid and plant pigments (Jigam et al. 2010). *Acacia modesta* has tranquillizer and anti-inflammatory effects, as well as analgesic effects related to the opioid regulation (Bukhari et al. 2010). The flower extracts of *Acacia dealbata* contain approximately 25% phenolic compounds, leading to possess it different biological properties such as tumour cells killing, antitoxins and anti-inflammatory (Casas et al. 2020).

The stem bark extracts of *A. nilotica* have a strong antibacterial effect against *S. aureus*, *Proteus mirabilis* and *Klebsiella pneumoniae*; phytochemical analyses of extracts showed existences anthraquinones, saponins, tannins and flavonoids (Deshpande 2013). In another study, the outcomes showed that the methanolic extracts of *A. farnesiana* exhibited good antimicrobial effect, getting suppression zones approximately 2.8 cm against *Vibrio cholerae*, as well as, has been isolated and diagnosed methyl gallate compound which has efficient against the last microbe (Sánchez et al. 2013). *A. polyacantha* leaf extracts also showed significant anti-staphylococcal action, this activity is attributed to the existence of epicatechin compound in the extracts (Ashu et al. 2020). The extracts of *Acacia* pods and leaves showed antimalarial and antibacterial properties (Sadiq et al. 2017).

*A. nilotica* used in the folk medication to prevent the growth of some pathogen fungi (Safavi et al. 2015). *A. nilotica* showed potent activity versus *Aspergillus fumigatus*, due to its nilobamate as a modern compound for better treatment against some pathogenic fungi (Mbatchou and Oumar 2012). *A. nilotica* has an antiparasite activity, specifically to reduce the growth of trypanosomes (Sulaiman et al. 2020).

Also, an aqueous extract of *A. nilotica* leaves showed inhibition impacts against some type of fungi including *Candida albicans*, *Aspergillus niger* and *A. fumigatus* (Sharma et al. 2014b). All the extracts of the *Acacia sinuata* contain a considerable

amount of phenol and various types of plant pigments (flavonoids), and they also exhibited antifungal activity (Vijayasekhar et al. 2016). Leaves and fruits of *A. nilotica* aqueous extracts showed inhibitory effects against Bovine Herpes Virus type-1 (BHV1); the highest ratio of inhibition was 61.1% at concentration 0.156 mg/ml for leaf extract (Goel et al. 2011). Leaf extract of *Acacia mellifera* showed anti-HBV efficiency (Malviya et al. 2011). Caffeoyl and coumaroyl extracted from leaves of *Acacia cochliacantha* had anthelmintic action against *Haemonchus contortus* (Castillo-Mitre et al. 2017).

### 19.4.2 The Industrial Importance of Acacia

*Acacia* is an important species and plays a varied role in the livelihoods of rustic populations in all sides of the world (Miller et al. 2011). While *Acacia* lumber was previously utilized for building boats or ships as well as bridges, currently, it is utilized to produce furniture. Researchers worked to introduce even better wood quality cultivation of *Acacia* such as *Acacia* hybrid and second-generation *Acacia mangium* (Jusoh et al. 2014).

The existence of chemicals used for antiinsect applications is considered harmful to cultivated plants and animals in nature, and it is considered a big environmental concern and their unfavourable effect on human health (Gill and Garg 2014). Coal of *Acacia etbaica* was found to be an efficient and cheap alternative for the elimination of a large group of pesticides and other synthetic organic compounds with chlorinated aromatic molecules from water solutions (Gebrekidan et al. 2015). *A. nilotica* extract is used to colour woollen yarns, which showed high stability after washing; also, it possesses antioxidant and antipoisoning activity (Rather et al. 2017). In a previous study, the various solvents for obtaining colour from a tropical *Acacia* (*A. nilotica*) bark and their effectiveness, water, acidic, alcoholic and alkali solvents were studied. A dye obtaining in alkali exhibited high colour potential with more stability (Kumar et al. 2015). The product of biofuel intended as a substitute for diesel from *A. nilotica* seeds oil, which contains a high level of unsaturated fatty acid, is also highlighted (Adhikesavan et al. 2015). *Acacia* biomass (*A. mangium* and *A. auriculiformis*) may be used as a raw material in heating decomposition (Ahmed et al. 2018). *A. mangium* was also used to produce fuel pellets (Amirta et al. 2018). *Acacia concinna* were used to synthesize eco-friendly silver nanoparticles which could have many industrial and medical applications (Kumar Sur et al. 2018). In the food biotechnology industry, the leaf extracts of *Acacia leptoloba*, *Acacia auriculiformis* and *Acacia disparrima* have the potential to prevent bacteria which caused food toxicity (Cock 2012). *Acacia* gum can be used to limit some biological activities, by adding it in the culture media as an antibacterial agent (Dwivedi et al. 2020). Gum powder of *A. modesta* may be utilized for decreasing shrink, internal treating inside the Source Code Control System (SCCS), for promoting the viscosity of the cementitious systems (Rizwan et al. 2018). Moreover, the wide range of antimicrobial ability indicates the possibility to use *Acacia* trees

extracts as natural feed keeper (Cock 2017). Also, Arabic gum utilized with canella and garlic as an alternative, natural meat and fishes preservatives (Rakshit and Ramalingam 2013).

High level of phenolic compounds in the flowers *Acacia* extracts showed activity against *Salmonella enterica* and *Escherichia coli*; this led to using them as preservative substances in the feed, medication and the manufacture of cosmetic (Stankov et al. 2018). Another study in vivo proved that the cream which contains *Acacia* bark extracts decreases sebaceous glands excretions (Atif Ali et al. 2012). As well, *Acacia concinna* pods support hair growth and prevent appearance small pieces of dead skin (Gediya et al. 2011). Recently, *Acacia* trees have contributed to the manufacturing of furniture, fibre concrete, gates and car parts characterized by rapidly degradable, friendly of environment, lightweight and strong (Muhammad et al. 2019).

### 19.4.3 Environmental Impact

In case of environmental alteration and its negative impact to forests globally, *Acacia* trees are considered one of the most successful forest trees to resist drought and climate change in the world due to its root system, where *Acacia tortilis* has a major ability to resist the cruelty of drought (Aref et al. 2013; Winters et al. 2018). *A. mangium* is a species with significant potential for phytoremediation and its capacity to transport heavy minerals such as aluminium and iron (Zuhaidi and Vijayanathan 2018). Other minerals such as zinc, copper and cadmium can be treated by using *A. mangium* (Majid et al. 2011). It has been shown that extracts of *A. concinna* pods had high performance and qualification as anticorrosion substances (Haldhar et al. 2020). *Acacia saligna* and *A. polyacantha* exhibited guide of cumulation of Ni, Cu and Fe and thus may be utilized for phytoremediation (Masvodza et al. 2013). Although *A. mangium* have a positive impact on the ecosystems but may be negatively interfering with other types of trees (Koutika and Richardson 2019). *Acacia seyal* negatively affected sorghum yield, due to competition for shading and nutrients (Deng et al. 2017). Mixing between *A. mangium* and *Eucalyptus grandis* led to the exploration of deep soil with a positive impact of forest (Germon et al. 2018). *A. nilotica* can be used as an indicator of the presence of air pollutants such as copper and cobalt (Attahiru et al. 2015). *Acacia raddiana* showed the ability to boost the potential of microbial groups and enhances carbon and nitrogen content in soil (Fterich et al. 2012; Pereira et al. 2018). Polypropylene compounds extraction from dark *Acacia* bark have good properties, such as higher strength and extreme crystallization heat and thermic stabilization (Taflick et al. 2015). *A. concinna* pod extracts exhibited a repressive effect against weeds in agriculture crops (Boonmee and Kato-Noguchi 2017). The water extracts of the phylloides, roots, stalks, seeds and blooms of *Acacia cyanophylla* exhibited inhibition on the seed germination of two weeds *Silybum marianum* L. and *Peganum harmala* L. (El Ayebe et al. 2013). *Acacia seyal* seeds have impacted on growing and produc-

tion of *Sorghum bicolor* positively in *Striga hermonthica*-invaded region (Eltayb et al. 2013). *Acacia* trees help to reduce the temperature surrounding urban environment, by increasing the shade (Aguilera et al. 2015). It also improves water and air quality through the absorbance of pollutants and interferes with dust and small particles (Attahiru et al. 2015), as well as oxygen production and reduction of ozone erosion (Abbasi and Abbasi 2017). It reduces wind risk and speed (Wittmann et al. 2018).

## 19.5 Conclusion

Multi-usage plants have been utilized and cultivated by humans for thousands of years for different purposes. It is all started by the utilization for food consumption of the wild plants and then growing those plants for remedies, and then it progressed to be utilized in different aspects of life. The examples of this are the four plants given within this chapter representing a group of plants which could be a good candidate to be cultivated for medicinal and pharmaceutical purposes and at the same time directly or indirectly will be of great benefit to the environment in terms of increasing oxygen rate and reducing the carbon footprint. More efforts from government and non-governmental organization need to be directed to the cultivation of these plants especially at the local communities in many developing countries for economical, environmental and social benefits.

## References

- Abbasi S, Abbasi T (2017) Impacts of ozone hole. In: Ozone hole. Springer, New York, NY, pp 51–99
- Abd El-Hack ME, Alagawany M, Elrys AS, Desoky E-SM, Tolba H, Elnahal AS, Elnesr SS, Swelum AA (2018) Effect of forage *Moringa oleifera* L. (moringa) on animal health and nutrition and its beneficial applications in soil, plants and water purification. *Agriculture* 8(9):145
- Abdelbasit H, Mahgoup S, ElDoma A (2014) Variation in seed morphometric characteristics and germination of *Acacia tortilis* subspecies *raddiana* and subspecies *spirocarpa* among three provenances in Sudan. *Global J Biotechnol* 3(2):191–196
- Abdel-Mageed WM, Bayoumi SALH, Salama AAR, Salem-Bekhit MM, Abd-Alrahman SH, Sayed HM (2014) Antioxidant lipooxygenase inhibitors from the leaf extracts of *Simmondsia chinensis*. *Asian Pac J Trop Med* 7:S521–S526
- Abdel-Mageed WM, Bayoumi SA, Al-Wahaibi LH, Li L, Sayed HM, Abdelkader MS, El-Gamal AA, Liu M, Zhang J, Zhang L (2016) Noncyanogenic cyanoglucoside cyclooxygenase inhibitors from *Simmondsia chinensis*. *Org Lett* 18(8):1728–1731
- Abdel-Mohsen A, Abdel-Rahman R, Kubena I, Kobera L, Spatz Z, Zboncak M, Prikryl R, Brus J, Jancar J (2020a) Chitosan-glucan complex hollow fibers reinforced collagen wound dressing embedded with aloe vera. Part I: preparation and characterization. *Carbohydr Polym* 230:115708
- Abdel-Mohsen A, Frankova J, Abdel-Rahman R, Salem A, Sahffie N, Kubena I, Jancar J (2020b) Chitosan-glucan complex hollow fibers reinforced collagen wound dressing embedded with

- Aloe vera. II. Multifunctional properties to promote cutaneous wound healing. *Int J Pharm* 582:119349
- Abdel-Wahhab MA, Joubert O, El-Nekeety AA, Sharaf HA, Abu-Salem FM, Rihn BH (2016) Dietary incorporation of jojoba extract eliminates oxidative damage in livers of rats fed fumonisin-contaminated diet. *Hepatoma Res* 2:78–86
- Abdull Razis AF, Ibrahim MD, Kntayya SB (2014) Health benefits of *Moringa oleifera*. *Asian Pac J Cancer Prev* 15(20):8571–8576
- Abdullaeva Z (2017) Phyto-synthesis of nanomaterials. In: Abdullaeva Z (ed) *Synthesis of nanoparticles and nanomaterials: biological approaches*. Springer International Publishing, Cham, pp 79–101. [https://doi.org/10.1007/978-3-319-54075-7\\_4](https://doi.org/10.1007/978-3-319-54075-7_4)
- Abu-Salem F, Ibrahim HM (2014) Antimicrobial activity and phytochemicals screening of jojoba (*Simmondsia chinensis*) root extracts and latex. *Int J Biol Biomed Agric Food Biotechnol Eng* 8(5):516–522
- Adesina B, Omitoyin B (2011) Potential of *Moringa oleifera* (Lam.) fresh root-bark extract as an organic piscicide in aquaculture pond management. *Egypt J Biol* 13(1):8–13
- Adhikesavan C, Rajagopal K, SelwinRajaduari J (2015) Production and characterization of bio-diesel from *Acacia nilotica* seeds. *Int J ChemTech Res* 8:854–859
- Adzitey F, Agbolosu A, Udoka UJ (2019) Antibacterial effect of Aloe Vera gel extract on *Escherichia coli* and *Salmonella enterica* isolated from the gastrointestinal tract of Guinea fowls. *WORLD* 9(3):166–173
- Afzal I, Hussain B, Basra S, Rehman H (2012) Priming with moringa leaf extract reduces imbibitional chilling injury in spring maize. *Seed Sci Technol* 40(2):271–276
- Afzal I, Zia S, Kausar S, Hazrat A, Jan T, Anwar M, Riaz M, Khan FS, Akram M, Rasool G (2020) Dose response relationship of Aloe vera to cure atopic dermatitis in rats. *Dermatol Ther*
- Agarwal S, Khan S (2018) Comparative molecular and chemical fingerprinting found accession “Clone-64” as the best genetic material for jojoba industry. *Meta Gene* 17:115–123
- Agarwal S, Kumari S, Mudgal A, Khan S (2020) Green synthesized nanoadditives in jojoba biodiesel-diesel blends: an improvement of engine performance and emission. *Renew Energy* 147:1836–1844
- Agra-Neto AC, Napoleão TH, Pontual EV, de Lima Santos ND, de Andrade Luz L, de Oliveira CMF, de Melo-Santos MAV, Coelho LCBB, Navarro DMAF, Paiva PMG (2014) Effect of *Moringa oleifera* lectins on survival and enzyme activities of *Aedes aegypti* larvae susceptible and resistant to organophosphate. *Parasitol Res* 113(1):175–184
- Aguilera N, Sanhueza C, Guedes LM, Becerra J, Carrasco S, Hernández V (2015) Does *Acacia dealbata* express shade tolerance in Mediterranean forest ecosystems of South America? *Ecol Evol* 5(16):3338–3351. <https://doi.org/10.1002/ece3.1606>
- Agyepong AO (2009) The possible contribution of *Moringa oleifera* lam. leaves to dietary quality in two Bapedi communities in Mokopane, Limpopo Province. University of South Africa, Ahmed A, Bakar MSA, Azad AK, Sukri RS, Mahlia TMI (2018) Potential thermochemical conversion of bioenergy from *Acacia* species in Brunei Darussalam: a review. *Renew Sust Energ Rev* 82:3060–3076
- Ahmet Ü, Nayir E, Ay H, Kirca Ö, Özdoğan M (2016) Aloe Vera and Cancer. *Turkish J Oncol* 31(2):68–72
- Akbar S (2020) *Acacia nilotica* (L.) Delile. (Fabaceae/Leguminosae). In: *Handbook of 200 medicinal plants*. Springer, Cham, Switzerland, pp 45–56
- Akl EM, Taha FS, Mohamed SS, Wagdy SM, Hamid SMA (2019) Effective treatments of jojoba and jatropha hulls to obtain phytochemical compounds for industrial, nutritional, and pharmaceutical uses. *Bull Natl Res Cent* 43(1):21
- Al Omari SA, Hamdan MO, Selim MY, Elnajjar E (2019) Combustion of jojoba-oil/diesel blends in a small scale furnace. *Renew Energy* 131:678–688
- Al-Abri M, Ashique M, Ramkumar A, Nemmar A, Ali BH (2018) Motor and behavioral effects of *Moringa oleifera* leaf extract. *Nat Prod Commun* 13(1):1934578X1801300126

- Alapati P, Sulthana S (2015) Phytochemical screening of 20 plant sources for textiles finishing. *Int J Adv Res* 3(10):1391–1398
- Aldababseh A, Temimi M, Maghelal P, Branch O, Wulfmeyer V (2018) Multi-criteria evaluation of irrigated agriculture suitability to achieve food security in an arid environment. *Sustainability* 10(3):803
- Al-Dossary O, Kharabian A, Al-Mssallem I, Furtado A, Henry R (2020) Transcriptomics analysis for the detection of novel drought tolerance genes in jojoba (*Simmondsia Chinensis*). *Multidiscipl Digital Publish Institute Proc* 36(1):135
- Alegbeleye OO (2018) How functional is *Moringa Oleifera*? A review of its nutritive, medicinal, and socioeconomic potential. *Food Nutr Bull* 39(1):149–170
- Al-Ghamdi A, Elkholy T, Abuhelal S, Alabbadi H, Qahwaji D, Sobhy H, Khalefah N, Abu-Hilal M (2017) Study of jojoba (*Simmondsia chinensis*) oil by gas chromatography. *Nat Prod Chem Res* 5(282):2
- Al-Ghamdi A, Elkholy T, Abuhelal S, Al-Abbadi H, Qahwaji D, Khalefah N, Sobhy H, Abu-Hilal M (2019) Antibacterial and antifungal activity of jojoba wax liquid (*Simmondsia chinensis*). *Pharm J* 11(1):191–194. <https://doi.org/10.5530/pj.2019.11.31>
- Alhakmani F, Kumar S, Khan SA (2013) Estimation of total phenolic content, in-vitro antioxidant and anti-inflammatory activity of flowers of *Moringa oleifera*. *Asian Pac J Trop Biomed* 3(8):623
- Al-Hamamre Z (2013) Jojoba is a possible alternative green fuel for Jordan. *Energ Sourc B Energ Econ Plann* 8(3):217–226
- Ali HA, Yagoub SO, Hamza NB (2015) Chemical analysis of *Moringa oleifera* and *M. peregrina* and their growth responses to water stress under semi-desert condition of Sudan. *J Appl Life Sci* 3:7–14
- Al-Obaidi JR (2019) Contribution of jojoba (*Simmondsia chinensis*) products in human health. In: Ozturk M, Hakeem KR (eds) *Plant and human health, volume 2: Phytochemistry and molecular aspects*. Springer International Publishing, Cham, pp 303–312. [https://doi.org/10.1007/978-3-030-03344-6\\_12](https://doi.org/10.1007/978-3-030-03344-6_12)
- Al-Obaidi JR, Suliman BK, Al-Ani NK (2013) Molecular-based marker for sex differentiation of jojoba in vivo and in vitro Iraqi cultivars using RAPD-PCR technique. *Sci Res Essays* 7(4):522–527
- Al-Obaidi JR, Halabi MF, AlKhalifah NS, Asanar S, Al-Soqeer AA, Attia MF (2017a) A review on plant importance, biotechnological aspects, and cultivation challenges of jojoba plant. *Biol Res* 50(1):25
- Al-Obaidi JR, Rahmad N, Hanafi NM, Halabi MF, Al-Soqeer AA (2017b) Comparative proteomic analysis of male and female plants in jojoba (*Simmondsia chinensis*) leaves revealed changes in proteins involved in photosynthesis, metabolism, energy, and biotic and abiotic stresses. *Acta Physiol Plant* 39(8):179. <https://doi.org/10.1007/s11738-017-2485-7>
- Alotaibi J, Yousif B (2016) Biolubricants and the potential of waste cooking oil. In: *Ecotribology*. Springer, Cham, Switzerland, pp 125–143
- Alotaibi S, Ali E, Darwesh H, Ahmed A-T, Al-Thubaiti E (2019) Effect of proline on growth and nutrient uptake of *Simmondsia chinensis* (link) Schneider under salinity stress. *Sciences* 22(9):412–418
- Al-Zoubi H, Zubair M, Manzar MS, Manda AA, Blaisi NI, Qureshi A, Matani A (2020) Comparative adsorption of anionic dyes (Eriochrome black T and Congo red) onto jojoba residues: isotherm, kinetics and thermodynamic studies. *Arab J Sci Eng* 45:7275–7287
- Amadou I, Soulé M, Salé A (2020) An overview on the importance of *Acacia nilotica* (L.) Willd. Ex Del.: a review. *Asian J Agric Res Forest* 5:12–18
- Amirta R, Anwar T, Suwianti W (2018) Trial production of fuel pellet from *Acacia mangium* bark waste biomass. In: *IOP conference series: earth and environmental science, vol 1*. IOP Publishing, Bristol, UK, 012040
- Anwar F, Latif S, Ashraf M, Gilani AH (2007) *Moringa oleifera*: a food plant with multiple medicinal uses. *Phytother Res* 21(1):17–25

- Arafat S, Basuny A (2018) Jojoba oil: anew media for frying process. *Current Trends Biomed Eng Biosci* 17:1–3. <https://doi.org/10.19080/CTBEB.2018.17.555952>
- Araiza-Lizarde N, Alcaraz-Meléndez L, Angulo-Escalante MA, Reynoso-Granados T, Cruz-Hernández P, Calderón-Vázquez CL (2017) Physicochemical composition of seed oil of wild jojoba populations in northwestern Mexico. *J Food Nutr Res* 5(6):443–450
- Araújo CS, Carvalho DC, Rezende HC, Almeida IL, Coelho LM, Coelho NM, Marques TL, Alves VN (2013) Bioremediation of waters contaminated with heavy metals using *Moringa oleifera* seeds as biosorbent. *Appl Bioremed Active Passive Appr* 23:227–255
- Aref IM, Ahmed AI, Khan PR, El-Atta HA, Iqbal M (2013) Drought-induced adaptive changes in the seedling anatomy of *Acacia ehrenbergiana* and *Acacia tortilis* subsp. *raddiana*. *Trees* 27(4):959–971
- Arya D, Khan S (2016) A review of *Simmondsia chinensis* (jojoba) “the desert gold”: A multipurpose oil seed crop for industrial uses. *J Pharm Sci Res* 8(6):381
- Ashour ML, Ayoub NA, Singab ANB, Al Azizi MM (2013) *Simmondsia Chinensis* (jojoba): a comprehensive pharmacognostic study. *J Pharmacogn Phytochem* 2(2):25–48
- Ashu FA, Na-Iya J, Wamba BE, Kamga J, Nayim P, Ngameni B, Beng VP, Ngadjui BT, Kuete V (2020) Antistaphylococcal activity of extracts, fractions, and compounds of *Acacia polyacantha* wild (Fabaceae). *Evid Based Complement Alternat Med* 2020:1–10
- Aslam MF, Basra SMA, Hafeez MB, Khan S, Irshad S, Iqbal S, Saqqid MS, Akram MZ (2019) Inorganic fertilization improves quality and biomass of *Moringa oleifera* L. *Agrofor Syst*. <https://doi.org/10.1007/s10457-019-00464-7>
- Atif Ali A, Akhtar N, Khan HMS (2012) Cream containing acacia bark extract significantly reduces skin sebum content in healthy volunteers. *J Sci Ind Res* 71:678–681
- Attahiru U, Birmin-Yauri U, Muhammad C (2015) *Acacia nilotica* as bioindicator of copper and cobalt pollution due to vehicular emission along the main entrance road of Usmanu Danfodiyo university, Sokoto-Nigeria. *Int J Adv Res Chem Sci* 2:1–8
- Avijgan M, Kamran A, Abedini A (2016) Effectiveness of Aloe vera gel in chronic ulcers in comparison with conventional treatments. *Iranian J Med Sci* 41(3 Suppl):S30
- Azad A, Rasul M, Khan M, Sharma SC, Islam R (2015) Prospect of *Moringa* seed oil as a sustainable biodiesel fuel in Australia: A review. *Proc Eng* 105:601–606
- Azzam MO, Al-Malah KI, Omari RM (2012) Jojoba oil/water emulsions stabilized by BSA and egg proteins: a study using conductivity technique. *J Dispers Sci Technol* 33(7):1000–1005
- Bagewadi HG, Rathor N (2014) Effect of Aloe vera on animal models of parkinson disease in mice. *Int J Pharm Bio Sci* 5(3):549–559
- Bajer D, Janczak K, Bajer K (2020) Novel starch/chitosan/Aloe Vera composites as promising biopackaging materials. *J Polym Environ* 28(3):1021–1039
- Bakeer S, Makpoul K, Abou-Ellail M (2017) Evaluation of ten jojoba clones (*Simmondsia chinensis*) grown under middle Sinai conditions. *Ind Crop Prod* 107:30–37
- Barapatre A, Aadil KR, Tiwary BN, Jha H (2015) In vitro antioxidant and antidiabetic activities of biomodified lignin from *Acacia nilotica* wood. *Int J Biol Macromol* 75:81–89
- Batista AB, Oliveira JT, Gifoni JM, Pereira ML, Almeida MG, Gomes VM, Da Cunha M, Ribeiro SF, Dias GB, Beltrami LM (2014) New insights into the structure and mode of action of Mo-CBP3, an antifungal chitin-binding protein of *Moringa oleifera* seeds. *PLoS One* 9(10):e111427
- Belhadj S, Hentati O, Hamdaoui G, Fakhreddine K, Maillard E, Dal S, Sigrist S (2018) Beneficial effect of jojoba seed extracts on hyperglycemia-induced oxidative stress in RINm5f beta cells. *Nutrients* 10(3):384
- Benítez S, Achaerandio I, Pujolà M, Sepulcre F (2015) Aloe vera as an alternative to traditional edible coatings used in fresh-cut fruits: A case of study with kiwifruit slices. *LWT-Food Sci Technol* 61(1):184–193
- Bhalsinge R, Rajbhoj S, Limaye M, Vaidya M, Rane P, Tilak A (2018) Anti-inflammatory and immunomodulatory activity of ethanol extract of Aloe vera gel. *Int J Pharm Sci Res* 9(2):832–835

- Bhaskar DA, Uttam KJ, Singh AM, Jayram CM, Bhanudas SR (2013) Plant exudates and mucilage as pharmaceutical excipients. *J Adv Pharm Educat Res* 3(4):387–402
- Bhaumik S, Mathew BR, Datta S (2019) Computational intelligence-based design of lubricant with vegetable oil blend and various nano friction modifiers. *Fuel* 241:733–743
- Bijina B, Chellappan S, Basheer SM, Elyas KK, Bahkali AH, Chandrasekaran M (2011) Protease inhibitor from *Moringa oleifera* leaves: isolation, purification, and characterization. *Process Biochem* 46(12):2291–2300
- Bilin M, Alshanableh F, Evcil A, Savas MA (2018) A comparative examination of the quality of Jojoba seed oil harvested on the mesaoria plain of Cyprus Island. In: 2018 2nd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), 2018. IEEE, pp 1–4
- Biswas SK, Chowdhury A, Das J, Roy A, Hosen SZ (2012) Pharmacological potentials of *Moringa oleifera* Lam.: a review. *Int J Pharm Sci Res* 3(2):305
- Boonmee S, Kato-Noguchi H (2017) Allelopathic activity of *Acacia concinna* pod extracts. *Emir J Food Agric* 29:250–255
- Brilhante RSN, Sales JA, Pereira VS, Castelo DDSCM, de Aguiar Cordeiro R, de Souza Sampaio CM, Paiva MDAN, dos Santos JBF, Sidrim JJC, Rocha MFG (2017) Research advances on the multiple uses of *Moringa oleifera*: a sustainable alternative for socially neglected population. *Asian Pac J Trop Med* 10(7):621–630
- Brown JS, Kleiman R, Koritala S, Ashley DA (2016) Human sebum mimetics derived from botanical sources and methods for making the same. Google Patents
- Bukhari IA, Khan RA, Gilani AH, Ahmed S, Saeed SA (2010) Analgesic, anti-inflammatory and anti-platelet activities of the methanolic extract of *Acacia modesta* leaves. *Inflammopharmacology* 18(4):187–196
- Carvalho PN, Basto MCP, Almeida CMR, Brix H (2014) A review of plant–pharmaceutical interactions: from uptake and effects in crop plants to phytoremediation in constructed wetlands. *Environ Sci Pollut Res* 21(20):11729–11763
- Casas MP, Conde E, Ribeiro D, Fernandes E, Domínguez H, Torres MD (2020) Bioactive properties of *Acacia dealbata* flowers extracts. *Waste Biomass Valorizat* 11(6):2549–2557. <https://doi.org/10.1007/s12649-019-00639-4>
- Castillo-Mitre G, Olmedo-Juárez A, Rojo-Rubio R, González-Cortázar M, Mendoza-de Gives P, Hernández-Beteta E, Reyes-Guerrero D, López-Arellano M, Vázquez-Armijo J, Ramírez-Vargas G (2017) Caffeoyl and coumaroyl derivatives from *Acacia cochliacantha* exhibit ovidical activity against *Haemonchus contortus*. *J Ethnopharmacol* 204:125–131
- Cellini L, Di Bartolomeo S, Di Campli E, Genovese S, Locatelli M, Di Giulio M (2014) In vitro activity of *Aloe vera* inner gel against *helicobacter pylori* strains. *Lett Appl Microbiol* 59(1):43–48
- Cerf ME (2013) Beta cell dysfunction and insulin resistance. *Front Endocrinol* 4:37
- Cevada E, Flores CA, López A, Álvarez F, Vázquez F (2017) Study of the thermal stability of jojoba oil used as antifoaming agent in petroleum industry. *J Therm Anal Calorim* 128(1):357–367
- Chaitanya S, Singh I (2016) Novel *Aloe Vera* fiber reinforced biodegradable composites—development and characterization. *J Reinf Plast Compos* 35(19):1411–1423
- Chaitanya S, Singh I (2018) Ecofriendly treatment of *aloe vera* fibers for PLA based green composites. *Int J Precis Eng Manuf-Green Technol* 5(1):143–150
- Chaudhary V, Tripathi R (2017) Feeding deterrence effects of defatted jojoba (*Simmondsia chinensis*) meal against Indian gerbil, *Tatera indica* (Hardwicke). *Proc Natl Acad Sci India Sect B Biol Sci* 87(3):663–670
- Chinma C, Gbadamosi K, Ogunsina B, Oloyede O, Salami S (2014) Effect of addition of germinated *moringa* seed flour on the quality attributes of wheat-based cake. *J Food Process Preserv* 38(4):1737–1742
- Chinnadurai GS, Krishnan S, Perumal P (2018) Studies on detection and analysis of proteases in leaf extract of medicinally important plants. *Phytomedicine* 40:176–188. <https://doi.org/10.1016/j.phymed.2018.01.011>

- Choudhary M, Kochhar A, Sangha J (2014) Hypoglycemic and hypolipidemic effect of Aloe vera L. in non-insulin dependent diabetics. *J Food Sci Technol* 51(1):90–96
- Choudhary S, Tak N, Bissa G, Chouhan B, Choudhary P, Sprent JI, James EK, Gehlot HS (2020) The widely distributed legume tree *Vachellia* (*Acacia*) nilotica subsp. indica is nodulated by genetically diverse Ensifer strains in India. *Symbiosis* 80(1):15–31
- Christaki EV, Florou-Paneri PC (2010) Aloe vera: a plant for many uses. *J Food Agric Environ* 8(2):245–249
- Chukwuebuka E (2015) *Moringa oleifera* “the mother’s best friend”. *Int J Nutrit Food Sci* 4(6):624–630
- Clericuzio M, Burlando B, Gandini G, Tinello S, Ranzato E, Martinotti S, Cornara L (2014) Keratinocyte wound healing activity of galactoglycerolipids from the fern *Ophioglossum vulgatum* L. *J Nat Med* 68(1):31–37
- Cock I (2012) Antimicrobial activity of *Acacia aulacocarpa* and *Acacia complanta* methanolic extracts. *Pharmacogn Commun* 2(1):66–71
- Cock IE (2017) Australian *Acacia* spp. extracts as natural food preservatives: growth inhibition of food spoilage and food poisoning bacteria. *Pharmacogn Commun* 7(1):4–15
- Daba MH (2016) Miracle tree: a review on multi-purposes of *Moringa oleifera* and its implication for climate change mitigation. *J Earth Sci Climat Change* 7(8). <https://doi.org/10.4172/2157-7617.1000366>
- Dachana KB, Jyotsna R, Indrani D, Jamuna P (2010) Effect of dried *Moringa* (*Moringa oleifera* Lam) leaves on rheological, microstructural, nutritional, textural and organoleptic characteristics of cookies. *J Food Qual* 33(5):660–677
- Dadashzadeh A, Imani R, Moghassemi S, Omidfar K, Abolfathi N (2020) Study of hybrid alginate/gelatin hydrogel-incorporated niosomal Aloe vera capable of sustained release of Aloe vera as potential skin wound dressing. *Polym Bull* 77(1):387–403
- Das DC, Sinha NK, Patsa MK, Das M (2015) Investigation of herbals for the treatment of leucorrhoea from south West Bengal, India. *Int J Bioassays* 4(11):4555–4559
- Dasgupta S, Roy B (2010) Antiparasitic activity of methanolic extract of *Acacia oxyphylla* (*Leguminosae*) against *Raillietina echinobothrida*. *J Parasit Dis* 34(1):14–19
- Daud FS, Kulkarni SB (2011) Comparative evaluation of photo-protective effect of Aloe vera *Tourn. ex Linn.* on UV damage in different Asian hair types. *Indian J Nat Prod Resour* 2(2):179–183
- De Oliveira CFR, Luz LA, Paiva PMG, Coelho LCBB, Marangoni S, Macedo MLR (2011) Evaluation of seed coagulant *Moringa oleifera* lectin (cMoL) as a bioinsecticidal tool with potential for the control of insects. *Process Biochem* 46(2):498–504
- del Real-Olvera J, Rustrian-Portilla E, Houbron E, Landa-Huerta FJ (2016) Adsorption of organic pollutants from slaughterhouse wastewater using powder of *Moringa oleifera* seeds as a natural coagulant. *Desalin Water Treat* 57(21):9971–9981
- Deng B, Tammeorg P, Luukkanen O, Helenius J, Starr M (2017) Effects of *Acacia seyal* and biochar on soil properties and sorghum yield in agroforestry systems in South Sudan. *Agrofor Syst* 91(1):137–148
- Deshpande SN (2013) Preliminary phytochemical analysis and in vitro investigation of antibacterial activity of *Acacia Nilotica* against clinical isolates. *J Pharmacogn Phytochem* 1(5):23–27
- Dey P, Karuna D, Bhakta T (2014) Medicinal plants used as anti-acne agents by tribal and non-tribal people of Tripura, India. *Am J Phytomed Clin Therap* 2(5):556–570
- Dinesh D, Murugan K, Madhiyazhagan P, Panneerselvam C, Kumar PM, Nicoletti M, Jiang W, Benelli G, Chandramohan B, Suresh U (2015) Mosquitocidal and antibacterial activity of green-synthesized silver nanoparticles from Aloe vera extracts: towards an effective tool against the malaria vector *Anopheles stephensi*? *Parasitol Res* 114(4):1519–1529
- Du Y, Pan K, Yu C, Luo B, Gu W, Sun H, Min Y, Liu D, Geng Y, Han W (2018) Plant diversity decreases net global warming potential integrating multiple functions in microcosms of constructed wetlands. *J Clean Prod* 184:718–726

- Dubey DK, Dora J, Kumar A, Gulsan RK (2013) A multipurpose tree—*Moringa oleifera*. *Int J Pharmaceut Chem Sci* 2(1):415–423
- Dwarakanath V, Dhanasree B, Jayasimha G, Nizamuddin B (2013) Anti-ulcer activity of *Acacia farnesiana* (L.) (Aroma) a lesser known folk-medicinal plant. *Int J Pharm Biol Sci* 3:145–152
- Dwivedi LM, Shukla N, Baranwal K, Gupta S, Siddique S, Singh V (2020) Gum *Acacia* modified Ni doped CuO nanoparticles: an excellent antibacterial material. *J Clust Sci* 31:1–11
- Eed AM, Burgoyne AH (2015) Propagation of *Simmondsia chinensis* (link) Schneider by stem cuttings. *Biol Chem Res* 2015:268–275
- El Ayeub A, Jannet HB, Skhiri FH (2013) Effects of *Acacia cyanophylla* Lindl. Extracts on seed germination and seedling growth of four crop and weed plants. *Turk J Biol* 37(3):305–314
- El Mogy N (2012) Germination of jojoba (*Simmondsia chinensis* L) seeds under the influence of several conditions. *J Environm Stud* 9:29–35
- Elnimiri K, Nimir H (2011) Biological and chemical assessment of the Sudanese jojoba (*Simmondsia chinensis*) oil. *Int J Nat Prod Pharm Sci* 2(1):28–39
- EL-Sabagh M, El-Kareem A, Sara M, Abd El Mageed ESN, Amin NS (2019) Comparative between two eco-friendly botanical oils through studies toxicological, biological and molecular impacts on the cotton Leafworm, *Spodoptera littoralis* (Boisd.). *Egypt Acad J Biol Sci F Toxicol Pest Control* 11(2):121–130
- Eltayb MTA, Magid TDA, Mohamed AG, Dirar AMA (2013) Effect of *Acacia seyal* (Del) seeds powder on growth and yield of sorghum bicolor (L) in *Striga hermonthica* (Del.) infested area. *J Forest Prod Indust* 2(6):18–25
- Eman NA, Tan CS, Makky EA (2014) Impact of *Moringa oleifera* cake residue application on waste water treatment: a case study. *J Water Resour Protect* 6(7):677–687
- Emmanuel S, Emmanuel B, Zaku S, Thomas S (2011) Biodiversity and agricultural productivity enhancement in Nigeria: application of processed *Moringa oleifera* seeds for improved organic farming. *Biol J North America* 2(5):867–871
- Eskander S, Kettmann KM, Ott J (2018) Plant morphology and behavior of *Simmondsia chinensis* in the Colorado Desert. *CEC Res*:1–8. <https://doi.org/10.21973/N3FH3N>
- Farzana M, Tharique I (2014) A review of ethnomedicine, phytochemical and pharmacological activities of *Acacia nilotica* (Linn) willd. *J Pharmacogn Phytochem* 3(1):84–90
- Fayed M, El-Deen M, Bastawy H, Sherif M (2018) Evaluation of jojoba oil efficacy in endodontic infection control. *Al-Azhar Dental J Girls* 5(1):15–22
- Ferreira R, Napoleão TH, Santos AF, Sá R, Carneiro-da-Cunha M, Morais M, Silva-Lucca RA, Oliva MLV, Coelho L, Paiva PM (2011) Coagulant and antibacterial activities of the water-soluble seed lectin from *Moringa oleifera*. *Lett Appl Microbiol* 53(2):186–192
- Fox LT, Du Plessis J, Gerber M, Van Zyl S, Boneschans B, Hamman JH (2014) In vivo skin hydration and anti-erythema effects of *Aloe vera*, *Aloe ferox* and *Aloe marlothii* gel materials after single and multiple applications. *Pharmacogn Mag* 10(Suppl 2):S392
- Fox LT, Mazumder A, Dwivedi A, Gerber M, Du Plessis J, Hamman JH (2017) In vitro wound healing and cytotoxic activity of the gel and whole-leaf materials from selected aloe species. *J Ethnopharmacol* 200:1–7
- Ferich A, Mahdhi M, Mars M (2012) Impact of grazing on soil microbial communities along a chronosequence of *Acacia tortilis* subsp. *raddiana* in arid soils in Tunisia. *Eur J Soil Biol* 50:56–63
- Gadzirayi C, Masamha B, Mupangwa J, Washaya S (2012) Performance of broiler chickens fed on mature *Moringa oleifera* leaf meal as a protein supplement to soyabean meal. *Int J Poultry Sci* 11(1):5–10
- Gómez LLS, Luna-delRisco M, Cano RES (2015) Comparative study between *M. oleifera* and aluminum sulfate for water treatment: case study Colombia. *Environ Monit Assess* 187(10):668
- Gebrekidan A, Teferi M, Asmelash T, Gebrehiwet K, Hadera A, Amare K, Deckers J, Van Der Bruggen B (2015) *Acacia etbaica* as a potential low-cost adsorbent for removal of organochlorine pesticides from water. *J Water Resour Protect* 7(03):278

- Gediya SK, Mistry RB, Patel UK, Blessy M, Jain HN (2011) Herbal plants: used as a cosmetics. *J Nat Prod Plant Resour* 1(1):24–32
- Genaidy E, Atteya AK, Adss I (2016) Increase the economic value of jojoba (*Simmondsia chinensis*) yield using evaluation of distinctive clones grown under the Egyptian environmental conditions. *Int J Agric Technol* 12(1):145–165
- George G, Ajayi O, Oyemike A (2018) Effect of *Moringa oleifera* leaf aqueous extract on intra-ocular and blood pressure of normotensive adults in Edo state, Nigeria. *J Nigerian Optomet Assoc* 20(2):75–81
- Germon A, Guerrini IA, Bordron B, Bouillet J-P, Nouvellon Y, de Moraes Gonçalves JL, Jourdan C, Paula RR, Laclau J-P (2018) Consequences of mixing *Acacia mangium* and *Eucalyptus grandis* trees on soil exploration by fine-roots down to a depth of 17 m. *Plant Soil* 424(1–2):203–220
- Ghouila H, Meksi N, Haddar W, Mhenni M, Jannet HB (2012) Extraction, identification and dyeing studies of Isosalipurposide, a natural chalcone dye from *Acacia cyanophylla* flowers on wool. *Ind Crop Prod* 35(1):31–36
- Giannakoudakis DA, Hosseini-Bandegharai A, Tsafarakidou P, Triantafyllidis KS, Kornaros M, Anastopoulos I (2018) Aloe vera waste biomass-based adsorbents for the removal of aquatic pollutants: a review. *J Environ Manag* 227:354–364
- Gifoni JM, Oliveira JT, Oliveira HD, Batista AB, Pereira ML, Gomes AS, Oliveira HP, Grangeiro TB, Vasconcelos IM (2012) A novel chitin-binding protein from *Moringa oleifera* seed with potential for plant disease control. *Pept Sci* 98(4):406–415
- Gill HK, Garg H (2014) Pesticide: environmental impacts and management strategies. *Pesticides-Toxic Aspects* 8:187
- Glatthaar-Saalmüller B, Fal A, Schönknecht K, Conrad F, Sievers H, Saalmüller A (2015) Antiviral activity of an aqueous extract derived from *Aloe arborescens* mill. against a broad panel of viruses causing infections of the upper respiratory tract. *Phytomedicine* 22(10):911–920
- Gleed SJ, Franklin DC (2018) Purple-flowered wattle (*Acacia purpureopetala*): observations and surveys of a threatened plant found only in the Herberston-Irvinebank region. *North Queensland Naturalist* 48:57
- Goel A, Singh R, Dash S, Gupta D, Pillai A, Yadav S, Bhatia A (2011) Antiviral activity of few selected indigenous plants against bovine herpes Virus-1. *J Immunol Immunopathol* 13(1):30–37
- Gonzales MVM, Tolentino AG (2014) Extraction and isolation of the alkaloids from the *Samanea saman* (*Acacia*) bark: its antiseptic potential. *Int J Scientif Tech Res* 3:119–121
- Gonzalez AJ, Larraburu EE, Llorente BE (2015) *Azospirillum brasilense* increased salt tolerance of jojoba during in vitro rooting. *Ind Crop Prod* 76:41–48
- Gopalakrishnan L, Doriya K, Kumar DS (2016) *Moringa oleifera*: a review on nutritive importance and its medicinal application. *Food Sci Human Wellness* 5(2):49–56
- Guirguis OW, Elkader MFA, Nasrat AA (2013) Enhancing antimicrobial activity for chitosan by adding Jojoba liquid wax. *Mater Lett* 93:353–355
- Gull I, Javed A, Aslam MS, Mushtaq R, Athar MA (2016) Use of *Moringa oleifera* flower pod extract as natural preservative and development of SCAR marker for its DNA based identification. *Biomed Res Int* 2016:1–12
- Guo X, Mei N (2016) Aloe vera: a review of toxicity and adverse clinical effects. *J Environ Sci Health C* 34(2):77–96
- Gupta S, Zaid M, Kumar A, Singh Y (2020) Effect of Jojoba oil based biolubricant additive on the friction and wear characteristics of the Al-7Si alloy. *Mater Today Proc.* <https://doi.org/10.1016/j.matpr.2020.02.564>
- Haldhar R, Prasad D, Bhardwaj N (2020) Surface adsorption and corrosion resistance performance of *Acacia concinna* pod extract: an efficient inhibitor for mild steel in acidic environment. *Arab J Sci Eng* 45(1):131–141. <https://doi.org/10.1007/s13369-019-04270-2>
- Hamman JH (2008) Composition and applications of Aloe vera leaf gel. *Molecules* 13(8):1599–1616
- Hamza AA (2010) Ameliorative effects of *Moringa oleifera* Lam seed extract on liver fibrosis in rats. *Food Chem Toxicol* 48(1):345–355

- Hani ALQ, Ekbal ALK, Mhaidat NM, Maraqa A (2014) Antioxidant and antimicrobial activities of Jordanian *Simmondsia chinensis* (link) ck schneid. *Eur Sci J* 10(27):229–241
- Hassan A, Hassan MT, Youssif A (2019) Production of bio lubricant from jojoba oil. *Int J Eng Innovat Res* 8(4):146–153
- He A, Haskin A, Okoye GA (2017) Scarring Alopecias related to hairstyling practices. In: *Fundamentals of ethnic hair*. Springer, Cham, Switzerland, pp 111–121
- Heř M, Dziedzic K, Górecka D, Jędrusek-Golińska A, Gujska E (2019) Aloe vera (L.) Webb.: natural sources of antioxidants—a review. *Plant Foods Hum Nutr* 74:255–265
- Hormozi M, Assaei R, Boroujeni MB (2017) The effect of aloe vera on the expression of wound healing factors (TGFβ1 and bFGF) in mouse embryonic fibroblast cell: in vitro study. *Biomed Pharmacother* 88:610–616
- Hussain SA, Patil GR, Reddi S, Yadav V, Pothuraju R, Singh RRB, Kapila S (2017) Aloe vera (*Aloe barbadensis* Miller) supplemented probiotic lassi prevents *Shigella* infiltration from epithelial barrier into systemic blood flow in mice model. *Microb Pathog* 102:143–147
- Hwang CS, Lyga JW (2017) Hydroponic *Tiliacora Triandra* and Use Thereof. Google Patents
- Ibrahim A, Zakaria H, Agha M (2017) First report of leaf blight disease of jojoba (*Simmondsia chinensis*) caused by *Alternaria alternata* in Egypt. *J Plant Pathol Microbiol* 8:e111
- Iftikhar F, Arshad M, Rasheed F, Amraiz D, Anwar P, Gulfranz M (2010) Effects of acacia honey on wound healing in various rat models. *Phytother Res* 24(4):583–586
- Ince A, Karaca M (2011) Early determination of sex in jojoba plant by CAPS assay. *J Agric Sci* 149(3):327–336
- Inoti SK (2017) Genetic diversity in jojoba (*Simmondsia chinensis* L.) using simple sequence repeats in semi-arid areas of Kenya. *Int J Agricul Earth Sci* 3(4):36–51
- Irfan HM, Khan NAK, Asmawi MZ (2020) Moringa oleifera Lam. leaf extracts reverse metabolic syndrome in Sprague Dawley rats fed high-fructose high fat diet for 60-days. *Arch Physiol Biochem*:1–7. <https://doi.org/10.1080/13813455.2020.1762661>
- Jaja-Chimedza A, Graf BL, Simmler C, Kim Y, Kuhn P, Pauli GF, Raskin I (2017) Biochemical characterization and anti-inflammatory properties of an isothiocyanate-enriched moringa (*Moringa oleifera*) seed extract. *PLoS One* 12(8)
- Jelassi A, El Ayeb-Zakhama A, Nejma AB, Chaari A, Harzallah-Skhiri F, Jannet HB (2016) Phytochemical composition and allelopathic potential of three Tunisian *Acacia* species. *Ind Crop Prod* 83:339–345
- Jigam AA, Akanya HO, Dauda BE, Okogun J (2010) Polygalloyltannin isolated from the roots of *Acacia nilotica* Del.(Leguminosae) is effective against *Plasmodium berghei* in mice. *J Med Plants Res* 4(12):1169–1175
- Joseph B, Raj SJ (2010) Pharmacognostic and phytochemical properties of Aloe vera linn an overview. *Int J Pharmaceut Sci Rev Res* 4(2):106–110
- Joshi P, Mehta D (2010) Effect of dehydration on the nutritive value of drumstick leaves. *J Metabol Syst Biol* 1(1):5–9
- Joshay K, Sharma CP, Kalarikkal N, Sandeep K, Thomas S, Pothan LA (2016) Evaluation of in-vitro cytotoxicity and cellular uptake efficiency of zidovudine-loaded solid lipid nanoparticles modified with Aloe Vera in glioma cells. *Mater Sci Eng C* 66:40–50
- Jusoh I, Zaharin FA, Adam NS (2014) Wood quality of *Acacia* hybrid and second-generation *Acacia mangium*. *Bioresources* 9(1):150–160
- Kaddam LA, Kaddam AS (2020) Effect of gum Arabic (*Acacia senegal*) on C-reactive protein level among sickle cell anemia patients. *BMC Res Notes* 13(1):1–5
- Kaddam LA, Fdl-Elmula I, Eisawi OA, Abdelrazig HA, Elnimeiri MK, Saeed AM (2019) Biochemical effects and safety of gum arabic (*Acacia Senegal*) supplementation in patients with sickle cell anemia. *Blood Res* 54(1):31–37
- Kanatt SR, Makwana SH (2020) Development of active, water-resistant carboxymethyl cellulose-poly vinyl alcohol-Aloe vera packaging film. *Carbohydr Polym* 227:115303
- Kang M-C, Kim SY, Kim YT, Kim E-A, Lee S-H, Ko S-C, Wijesinghe WAJP, Samarakoon KW, Kim Y-S, Cho JH, Jang H-S, Jeon Y-J (2014) In vitro and in vivo antioxidant activities of

- polysaccharide purified from aloe vera (*Aloe barbadensis*) gel. *Carbohydr Polym* 99:365–371. <https://doi.org/10.1016/j.carbpol.2013.07.091>
- Kannan KT, Rameshbabu S (2018) Tribological properties of modified jojoba oil as probable base stock of engine lubricant. *J Mech Sci Technol* 32(4):1739–1747
- Kara Y, Koca S, Vaizogullar HE, Kuru A (2013) Studying phytoremediation capacity of jojoba (*Simmondsia chinensis*) and sunflower (*Helianthus annuus*) in hydroponic systems. *Curr Opin Biotechnol* 24:S34
- Kassem G, Atta-Alla O, Ali F (2011) Improving the quality of beef burger by adding thyme essential oil and jojoba oil. *Archivos de zootecnia* 60(231):787–795
- Kaushik P, Pahwa P, Kaushik D (2014) A comprehensive review on medicinal plants with anticancer activity. *Glob J Pharmaceut Educat Res* 3(1–2)
- Kekuda TP, Mallikarjun N, Swathi D, Nayana K, Aiyar MB, Rohini T (2010) Antibacterial and antifungal efficacy of steam distillate of *Moringa oleifera* Lam. *J Pharm Sci Res* 2(1):34
- Keorochana K, Chaiyasuk P, Muangman P (2015) Prospective randomized-controlled comparison between silicone plus herbal extract gel versus Aloe vera gel for burn scar prophylaxis. *Wound Med* 9:1–4
- Khairi MM (2019) Genetics and breeding of jojoba [*Simmondsia chinensis* (link) Schneider]. In: *Advances in plant breeding strategies: industrial and food crops*. Springer, Cham, Switzerland, pp 237–276
- Khan D, Sahito ZA (2013) Variation in pod and seed sizes and seed packaging cost in *Acacia Stenophylla* A. Cunn. Ex. Benth.-an Australian wattle growing in Karachi, Pakistan. *FUUAST J Biol* 3(1):15–30
- Khan BA, Menaa F, Reich A, Caldeira E, Bakhsh S (2016) Potential phytotherapy of atopic dermatitis, acne, psoriasis, vitiligo. *Indian J Tradit Knowl* 15(4):531–573
- Khan S, Agarwal S, Sharma V (2017) Biochemical and molecular studies on the commercial oil-yielding desert shrub *Simmondsia chinensis* (jojoba, a desert gold). *Oilseed Crops: Yield and Adaptations under Environmental Stress*, p 152
- Khattab EA, Amin GA (2018) Jojoba seed yield response to water stress under circumstances of Sinai. *Ann Res Rev Biol* 28:1–11
- Koutika L-S, Richardson DM (2019) *Acacia mangium* Willd: benefits and threats associated with its increasing use around the world. *Forest Ecosyst* 6(1):2
- Krist S (2020) Chaulmoogra oil. In: *Vegetable fats and oils*. Springer, Cham, Switzerland, pp 223–226
- Kulkarni KA, Zambare MS (2018) The impact study of houseplants in purification of environment using wireless sensor network. *Wirel Sens Netw* 10(3):59–69
- Kumar Sur U, Ankamwar B, Karmakar S, Halder A, Das P (2018) Green synthesis of silver nanoparticles using the plant extract of *Shikakai* and *Reetha*. *Materi Today Proc* 5(1, Part 2):2321–2329. <https://doi.org/10.1016/j.matpr.2017.09.236>
- Kumar M, Rakesh S, Nagpal R, Hemalatha R, Ramakrishna A, Sudarshan V, Ramagoni R, Shujaiddin M, Verma V, Kumar A (2013a) Probiotic *Lactobacillus rhamnosus* GG and Aloe vera gel improve lipid profiles in hypercholesterolemic rats. *Nutrition* 29(3):574–579
- Kumar S, Mangal M, Dhawan AK, Singh N (2013b) Callus induction and plant regeneration from leaf explants of jojoba [*Simmondsia chinensis* (link) Schneider]. *Indian J Biotechnol* 12:544–547
- Kumar A, Pareek P, Raja A, Shakyawar D (2015) Extraction from babul (*Acacia nilotica*) bark and efficacy of natural colour on woollen yarn. *Indian J Small Rumina (The)* 21(1):92–95
- Kumar S, Yadav A, Yadav M, Yadav JP (2017a) Effect of climate change on phytochemical diversity, total phenolic content and in vitro antioxidant activity of Aloe vera (L.) Burm. f. *BMC Res Notes* 10(1):60. <https://doi.org/10.1186/s13104-017-2385-3>
- Kumar S, Yadav M, Yadav A, Yadav J (2017b) Impact of spatial and climatic conditions on phytochemical diversity and in vitro antioxidant activity of Indian Aloe vera (L.) Burm. f. *S Afr J Bot* 111:50–59

- Kumar R, Singh AK, Gupta A, Bishayee A, Pandey AK (2019) Therapeutic potential of Aloe vera—A miracle gift of nature. *Phytomedicine* 60:152996
- Kumar S, Purohit CS, Kulloli RN (2020) Aloe trinervis sp. nov.: a new succulent species from Indian Desert (Asphodelaceae). *J Asia-Pacific Biodivers*. <https://doi.org/10.1016/j.japb.2020.03.001>
- Kumbhare M, Sivakumar T (2011) Anti-inflammatory and analgesic activity of stem bark of *Moringa oleifera*. *Pharmacologyonline* 3:641–650
- Labandeira CC, Prevec R (2014) Plant paleopathology and the roles of pathogens and insects. *Int J Paleopathol* 4:1–16
- Lacerda A, Vasconcelos ÉAR, Pelegrini PB, Grossi-de-Sa MF (2014) Antifungal defensins and their role in plant defense. *Front Microbiol* 5:116
- Lad V, Murthy Z (2013) Rheology of Aloe barbadensis Miller: a naturally available material of high therapeutic and nutrient value for food applications. *J Food Eng* 115(3):279–284
- Lake M (2015) Australian rainforest woods: characteristics, uses and identification. CSIRO Publishing. <https://doi.org/10.1071/9781486301805>
- Langmead L, Makins RJ, Rampton DS (2004) Anti-inflammatory effects of aloe vera gel in human colorectal mucosa in vitro. *Aliment Pharmacol Ther* 19(5):521–527
- Lemma B, Mohammed N (2016) Distribution and socio-economic impacts of *Prosopis juliflora* in Gamo Gofa, segen area people and South Omo zones, southern Ethiopia. *Int J Agricul Sci Technol* 4(1):19–27
- Li J, Chou H, Li L, Li H, Cui Z (2020) Wound healing activity of neferine in experimental diabetic rats through the inhibition of inflammatory cytokines and nrf-2 pathway. *Artif Cell Nanomed Biotechnol* 48(1):96–106
- Maan A, Nazir A, Khan M, Ahmad T, Zia R, Murid M (2018) The therapeutic properties and applications of Aloe vera: a review. *J Herb Med* 12:1–10. <https://doi.org/10.1016/j.hermed.2018.01.002>
- Mahmood KT, Mugal T, Haq IU (2010) *Moringa oleifera*: a natural gift-A review. *J Pharm Sci Res* 2(11):775
- Maiti R, Rodriguez HG, Manue JJ, Diaz JC, Tijerina HAD, Kumari CA (2016) Comparative petiole anatomy of 36 woody plant species in northeastern Mexico and its significance in taxonomy and adaptation. *Int J Bio-Res Stress Manag* 7(3):350–360
- Majid NM, Islam M, Justin V, Abdu A, Ahmadpour P (2011) Evaluation of heavy metal uptake and translocation by *Acacia mangium* as a phytoremediator of copper contaminated soil. *Afr J Biotechnol* 10(42):8373–8379
- Mallenakuppe R, Homabalegowda H, Gouri MD, Basavaraju PS, Chandrashekharaiiah UB (2015) History, taxonomy and propagation of *Moringa oleifera* – a review. *Crops* 3(3.28):3.15
- Mallenakuppe R, Homabalegowda H, Gouri MD, Basavaraju PS, Chandrashekharaiiah UB (2019) History, taxonomy and propagation of *Moringa oleifera* – a review. *Crops* 3(3.28):3.15
- Malviya S, Rawat S, Kharia A, Verma M (2011) Medicinal attributes of *Acacia nilotica* Linn. – a comprehensive review on ethnopharmacological claims. *Int J Pharm Life Sci* 2(6):830–837
- Manaheji H, Jafari S, Zaringhalam J, Reza zadeh S, Taghizadfarid R (2011) Analgesic effects of methanolic extracts of the leaf or root of *Moringa oleifera* on complete Freund's adjuvant-induced arthritis in rats. *Zhong xi yi jie he xue bao*. *J Chin Integrat Med* 9(2):216–222
- Mangale Sapana M, Chonde Sonal G, Raut PD (2012) Use of *Moringa oleifera* (drumstick) seed as natural absorbent and an antimicrobial agent for ground water treatment. *Res J Recent Sci* 1:31–40
- Manoharan S, Vishnupriya V, Gayathri R (2016) Phytochemical analysis and in vitro antioxidant activity of jojoba oil. *J Pharm Sci Res* 8(6):512
- Manvitha K, Bidya B (2014) Aloe vera: a wonder plant its history, cultivation and medicinal uses. *J Pharmacogn Phytochemist* 2(5):85–88
- Maskin S (2013) Treatment for meibomian gland dysfunction or obstruction. Google Patents
- Masvodza D, Dzomba P, Mhandu F, Masamba B (2013) Heavy metal content in *Acacia saligna* and *Acacia polyacantha* on slime dams: implications for phytoremediation. *J Experiment Agricult Int* 3:871–883

- Matiliunaite M, Paulauskiene T (2019) From concept to practice: manufacturing of bio-lubricants from renewable resources. *Biomass Convers Biorefin* 9(2):353–361
- Matsumoto Y, Ma S, Tominaga T, Yokoyama K, Kitatani K, Horikawa K, Suzuki K (2019) Acute effects of transdermal administration of Jojoba oil on lipid metabolism in mice. *Medicina* 55(9):594
- Maurya SK, Singh AK (2014) Clinical efficacy of *Moringa oleifera* Lam. Stems bark in urinary tract infections. *Int Schol Res Notices* 2014:906843. <https://doi.org/10.1155/2014/906843>
- Mbatchesu VC, Oumar AA (2012) Antifungal activity of Nilobamate isolated from *Acacia nilotica* wild. *Phytopharmacology* 3:208–213
- McKeon TA (2016) Emerging industrial oil crops. In: *Industrial oil crops*. Elsevier, USA, pp 275–341
- Michalak M (2018) The use of carrier oils in aromatherapy massage and their effect on skin. *Archi Physiother Glob Res* 22:3
- Miklaszewska M, Banaś A (2016) Biochemical characterization and substrate specificity of jojoba fatty acyl-CoA reductase and jojoba wax synthase. *Plant Sci* 249:84–92
- Miller JT, Murphy DJ, Brown GK, Richardson DM, González-Orozco CE (2011) The evolution and phylogenetic placement of invasive Australian *Acacia* species. *Divers Distrib* 17(5):848–860
- Mishra A, Mishra A, Chattopadhyay P (2011) Herbal cosmeceuticals for photoprotection from ultraviolet B radiation: a review. *Trop J Pharm Res* 10(3):351
- Misir J, Brishti FH, Hoque M (2014) Aloe vera gel as a novel edible coating for fresh fruits: a review. *Am J Food Sci Tech* 2(3):93–97
- Missio AL, Tischer B, dos Santos PS, Codevilla C, de Menezes CR, Barin JS, Haselein CR, Labidi J, Gatto DA, Petutschnigg A (2017) Analytical characterization of purified mimosa (*Acacia mearnsii*) industrial tannin extract: single and sequential fractionation. *Sep Purif Technol* 186:218–225
- Mogoşanu GD, Grumezescu AM (2014) Natural and synthetic polymers for wounds and burns dressing. *Int J Pharm* 463(2):127–136
- Mohammed KA-EF, Sarmiento-Franco L, Santos-Ricalde R, Solorio-Sanchez JF (2012) The nutritional effect of *Moringa oleifera* fresh leaves as feed supplement on Rhode Island red hen egg production and quality. *Trop Anim Health Prod* 44(5):1035–1040
- Mohammedelnour AA, Mirghani M, Kabbashi NA, Alam MZ, Musa KH, Aminah A (2017) Effect of solvent types on phenolics content and antioxidant activities of *Acacia polyacantha* gum. *Int Food Res J* 24(Suppl):S369–S377
- Molazem Z, Mohseni F, Younesi M, Keshavarzi S (2015) Aloe vera gel and cesarean wound healing: a randomized controlled clinical trial. *Global J Health Sci* 7(1):203
- Mridha M (2015) Prospects of moringa cultivation in Saudi Arabia. *J Appl Environ Biol Sci* 5(3):39–46
- Muangnoi C, Chingsuwanrote P, Praengamthanachoti P, Svasti S, Tuntipopipat S (2012) *Moringa oleifera* pod inhibits inflammatory mediator production by lipopolysaccharide-stimulated RAW 264.7 murine macrophage cell lines. *Inflammation* 35(2):445–455
- Muhammad A, Rahman MR, Hamdan S, Ervina J (2019) Possibility usage of *Acacia* wood bio-composites in application and appliances. In: *Acacia Wood Bio-composites*. Springer, pp 207–224
- Muni Swamy G, Ramesh G, Devi Prasad R, Meriga B (2020) Astragalín, (3-O-glucoside of kaempferol), isolated from *Moringa oleifera* leaves modulates leptin, adiponectin secretion and inhibits adipogenesis in 3T3-L1 adipocytes. *Arch Physiol Biochem*:1–7. <https://doi.org/10.1080/13813455.2020.1740742>
- Mwale M, Masika PJ (2015) In vivo anthelmintic efficacy of *Aloe ferox*, *Agave sisalana*, and *Gunnera perpensa* in village chickens naturally infected with *Heterakis gallinarum*. *Trop Anim Health Prod* 47(1):131–138
- Nair GR, Naidu GS, Jain S, Nagi R, Makkad RS, Jha A (2016) Clinical effectiveness of aloe vera in the management of oral mucosal diseases—a systematic review. *J Clin Diagn Res* 10(8):ZE01

- Nasir O, Umbach AT, Rexhepaj R, Ackermann TF, Bhandaru M, Ebrahim A, Artunc F, Kempe DS, Puchchakayala G, Siraskar B (2012) Effects of gum arabic (*Acacia senegal*) on renal function in diabetic mice. *Kidney Blood Press Res* 35(5):365–372
- Nasr M, Abdel-Hamid S, H Mofteh N, Fadel M, A Alyoussef A (2017) Jojoba oil soft colloidal nanocarrier of a synthetic retinoid: preparation, characterization and clinical efficacy in psoriatic patients. *Curr Drug Deliv* 14(3):426–432
- Nasser RM (2017) Investigation of the behavior of aminated jojoba derivatives as green corrosion inhibitors for mild steel at 0.5 N HCl. *Der Chem Sinica* 8(2017):123–132
- Nazeam JA, El-Hefnawy HM, Singab AB (2020) Structural characterization and in vitro cytokines modulation effect of new acetylated galactomannans from *Aloe arborescens*. *J Med Food* 0(0):1–9. <https://doi.org/10.1089/jmf.2019.0230>
- Ni Y, Tizard IR (2004) Analytical methodology: the gel-analysis of aloe pulp and its derivatives. In: *Aloes*. CRC Press, pp 129–144
- Nigussie Z, Tsunekawa A, Haregeweyn N, Adgo E, Tsubo M, Ayalew Z, Abele S (2020) Economic and financial sustainability of an *Acacia decurrens*-based Taungya system for farmers in the Upper Blue Nile Basin, Ethiopia. *Land Use Policy* 90:104331
- Noulèkoun F, Khamzina A, Naab JB, Khasanah NM, Van Noordwijk M, Lamers J (2018) Climate change sensitivity of multi-species afforestation in semi-arid Benin. *Sustainability* 10(6):1931
- Nourozi F, Sayyari M (2020) Enrichment of *Aloe vera* gel with basil seed mucilage preserve bioactive compounds and postharvest quality of apricot fruits. *Sci Hortic* 262:109041
- Odoms VM (2012) Hair growth conditioner. Google Patents
- Ogunsina BS, Indira T, Bhatnagar A, Radha C, Debnath S, Krishna AG (2014) Quality characteristics and stability of *Moringa oleifera* seed oil of Indian origin. *J Food Sci Technol* 51(3):503–510
- Okiki PA, Osibote I, Balogun O, Oyinloye B, Idris O, Adelegan O, Asoso S, Olagbemide P (2015) Evaluation of proximate, minerals, vitamins and phytochemical composition of *Moringa oleifera* Lam. cultivated in ado Ekiti, Nigeria. *Adv Biol Res* 9(6):436–443
- Olatunya OS, Olatunya AM, Anyabolu HC, Adejuyigbe EA, Oyelami OA (2012) Preliminary trial of *Aloe vera* gruel on HIV infection. *J Altern Complement Med* 18(9):850–853
- Omonhinmin C, Olomukoro E, Ayoola A, Egwim E (2020) Utilization of *Moringa oleifera* oil for biodiesel production: A systematic review. *AIMS Energ* 8(1):102
- Oryan A, Mohammadalipour A, Moshiri A, Tabandeh MR (2016) Topical application of *Aloe vera* accelerated wound healing, modeling, and remodeling: an experimental study. *Ann Plast Surg* 77(1):37–46
- Oryan A, Alemzadeh E, Mohammadi AA, Moshiri A (2019) Healing potential of injectable *Aloe vera* hydrogel loaded by adipose-derived stem cell in skin tissue-engineering in a rat burn wound model. *Cell Tissue Res* 377(2):215–227
- Othman Z, Bhatia S, Ahmad AL (2011) Influence of the Settability parameters for palm oil mill effluent(POME) pretreatment by using *Moringa Oleifera* seeds as an environmental friendly coagulant. *J Mater Sci Eng* 5(3):332–340
- Pamudji JS, Tri S, Lidia IF (2015) Microemulsion formulation of *Aloe vera* gel and *Apium graveolens* ethanol extract for optimizing hair growth promotion. *AJPCR* 8(4):319–323
- Park YI, Jo TH (2006) Perspective of industrial application of *Aloe vera*. In: *New perspectives on Aloe*. Springer, Boston, MA, pp 191–200
- Parwani L, Bhatnagar M, Bhatnagar A, Sharma V, Sharma V (2019) Gum acacia-PVA hydrogel blends for wound healing. *Vegetos* 32(1):78–91
- Pathak MK, Joshi A, Mer K, Katiyar JK, Patel VK (2019) Potential of bio-lubricants in automotive tribology. In: *Automotive tribology*. Springer, Singapore, pp 197–214
- Pazyar N, Yaghoobi R (2016) The potential anti-psoriatic effects of jojoba extract. *J Dermatol Res* 1(1):14–15
- Pazyar N, Yaghoobi R, Rafiee E, Mehrabian A, Feily A (2014) Skin wound healing and phytomedicine: a review. *Skin Pharmacol Physiol* 27(6):303–310

- Pereira A, Zagatto MR, Brandani CB, Mescolotti DL, Cotta SR, Gonçalves JL, Cardoso EJ (2018) Acacia changes microbial indicators and increases C and N in soil organic fractions in intercropped Eucalyptus plantations. *Front Microbiol* 9:655
- Perez-Rosales E, Alcaraz-Meléndez L, Puente M, Vázquez-Juárez R, Zenteno-Savín T, Morales-Bojórquez E (2018) Endophytic bacteria isolated from wild jojoba [*Simmondsia chinensis* L.(Schneider)] roots improve in vitro propagation. *Plant Cell Tissue Organ Cult* 135(3):515–522
- Plummer MP, Finnis ME, Phillips LK, Kar P, Bihari S, Biradar V, Moodie S, Horowitz M, Shaw JE, Deane AM (2016) Stress induced hyperglycemia and the subsequent risk of type 2 diabetes in survivors of critical illness. *PLoS One* 11(11)
- Pothuraju R, Sharma RK, Onteru SK, Singh S, Hussain SA (2016) Hypoglycemic and hypolipidemic effects of Aloe vera extract preparations: A review. *Phytother Res* 30(2):200–207
- Prabhu K, Murugan K, Nareshkumar A, Ramasubramanian N, Bragadeeswaran S (2011) Larvicidal and repellent potential of *Moringa oleifera* against malarial vector, *Anopheles stephensi* Liston (Insecta: Diptera: Culicidae). *Asian Pac J Trop Biomed* 1(2):124–129
- Prajapati AK, Das S, Mondal MK (2020) Exhaustive studies on toxic Cr (VI) removal mechanism from aqueous solution using activated carbon of Aloe vera waste leaves. *J Mol Liq*:112956
- Prenner G (2011) Floral ontogeny of *Acacia celastrifolia*: an enigmatic mimosoid legume with pronounced polyandry and multiple carpels. In: *Flowers on the tree of life*. Cambridge University Press, Cambridge, pp 256–278
- Qadir I (2009) Medicinal and cosmetological importance of Aloe vera. *Int J Nat Therap* 2:21–26
- Radha MH, Laxmipriya NP (2015) Evaluation of biological properties and clinical effectiveness of Aloe vera: a systematic review. *J Tradit Complement Med* 5(1):21–26
- Raguvaran R, Manuja BK, Chopra M, Thakur R, Anand T, Kalia A, Manuja A (2017) Sodium alginate and gum acacia hydrogels of ZnO nanoparticles show wound healing effect on fibroblast cells. *Int J Biol Macromol* 96:185–191
- Rahman S, Carter P, Bhattarai N (2017) Aloe vera for tissue engineering applications. *J Funct Biomater* 8(1):6
- Rahman MR, Kakar A, Hamdan S, Bakri M, Julai N, Khui PN (2019) Introduction of various types of Acacia wood. In: *Acacia Wood Bio-composites*. Springer, Cham, Switzerland, pp 1–21
- Rahmani N, Khademloo M, Vosoughi K, Assadpour S (2014) Effects of Aloe vera cream on chronic anal fissure pain, wound healing and hemorrhaging upon defecation: a prospective double blind clinical trial. *Eur Rev Med Pharmacol Sci* 18(7):1078–1084
- Raja RR, Sreenivasulu M, Vaishnavi S, Navyasri DM, Samatha G, Geethalakshmi S (2016) *Moringa oleifera* – an overview. *RA J Appl Res* 2(9):620–624
- Rajvaidhya S, Nagori B, Singh G, Dubey B, Desai P, Jain S (2012) A review on *Acacia Arabica*-an Indian medicinal plant. *Int J Pharm Sci Res* 3(7):1995
- Rakshit M, Ramalingam C (2013) Gum acacia coating with garlic and cinnamon as an alternate, natural preservative for meat and fish. *Afr J Biotechnol* 12(4):406–413
- Ramesh P, Prasad BD, Narayana K (2020) Characterization of Kenaf/Aloevera Fiber reinforced PLA-hybrid biocomposite. In: *Advances in applied mechanical engineering*. Springer, Singapore, pp 1061–1067
- Rani A, Zahirah N, Husain K, Kumolosasi E (2018) *Moringa* genus: a review of phytochemistry and pharmacology. *Front Pharmacol* 9:108
- Ranjbar R, Yousefi A (2018) Effects of aloe vera and chitosan nanoparticle thin-film membranes on wound healing in full thickness infected wounds with methicillin resistant *Staphylococcus aureus*. *Bull Emerg Trauma* 6(1):8
- Ranzato E, Martinotti S, Burlando B (2011) Wound healing properties of jojoba liquid wax: an in vitro study. *J Ethnopharmacol* 134(2):443–449
- Rastogi T, Bhutda V, Moon K, Aswar P, Khadabadi S (2009) Comparative studies on anthelmintic activity of *Moringa oleifera* and *Vitex negundo*. *Asian J Res Chem* 2(2):181–182
- Rather LJ, Mohammad F (2015) *Acacia nilotica* (L.): a review of its traditional uses, phytochemistry, and pharmacology. *Sustain Chem Pharm* 2:12–30

- Rather LJ, Akhter S, Padder RA, Hassan QP, Hussain M, Khan MA, Mohammad F (2017) Colorful and semi durable antioxidant finish of woolen yarn with tannin rich extract of *Acacia nilotica* natural dye. *Dyes Pigments* 139:812–819
- Reddy S, Kuber BK (2017) Analgesic, antipyretic and anti-inflammatory activities of *Moringa oleifera*. *Indian Drugs* 54:63–66
- Reetu K, Bhargavi TM, Subha AK (2020) *Moringa oleifera*: a health food for animal and human consumption. *Food Scientif Rep* 1(4):11–14
- Rizwan SA, Mahmood N, Mahmood U, Bier TA (2018) Response of self-compacting paste (SCP) systems containing *Acacia Modesta* gum. *Constr Build Mater* 161:398–406
- Robiansyah I, Hajar AS, Al-Kordy M, Ramadan A (2014) Current status of economically important plant *Moringa peregrina* (Forsk.) in Saudi Arabia: a review. *Int J Theoret Appl Sci* 6(1):79–86
- Rockwood J, Anderson B, Casamatta D (2013) Potential uses of *Moringa oleifera* and an examination of antibiotic efficacy conferred by *M. oleifera* seed and leaf extracts using crude extraction techniques available to underserved indigenous populations. *Int J Phytother Res* 3(2):61–71
- Rubio-Elizalde I, Bernáldez-Sarabia J, Moreno-Ulloa A, Vilanova C, Juárez P, Licea-Navarro A, Castro-Ceseña AB (2019) Scaffolds based on alginate-PEG methyl ether methacrylate-*Moringa oleifera*-*Aloe vera* for wound healing applications. *Carbohydr Polym* 206:455–467
- Saadabi AM, Zaid IA (2011) An in vitro antimicrobial activity of *Moringa oleifera* L. seed extracts against different groups of microorganisms. *Asian J Basic Appl Sci* 5:129–134
- Sabzaligol M, Safari N, Baghchejghi N, Latifi M, Bekhradi R, Taghizadeh M, Zareie F (2014) The effect of *Aloevera* gel on prineal pain & wound healing after episiotomy. *Complement Med J Facul Nurs Midwif* 4(2):766–775
- Sadiq MB, Tharaphan P, Chotivanich K, Tarning J, Anal AK (2017) In vitro antioxidant and antimicrobial activities of leaves, pods and bark extracts of *Acacia nilotica* (L.) Del. *BMC Complement Altern Med* 17(1):372. <https://doi.org/10.1186/s12906-017-1878-x>
- Safari V, Kamau J, Nthiga P, Ngugi M, Orinda G, Njagi E (2016) Antipyretic, antiinflammatory and antinociceptive activities of aqueous bark extract of *Acacia nilotica* (L.) Delile in albino mice. *Pain Manage Med* 2(113):2
- Safavi M, Shams-Ardakani M, Foroumadi A (2015) Medicinal plants in the treatment of *helicobacter pylori* infections. *Pharm Biol* 53(7):939–960
- Sahay S, Yadav U, Srinivasamurthy S (2017) Potential of *Moringa oleifera* as a functional food ingredient: a review. *Magnesium (g/kg)* 8 (9.06):4.90
- Sahu PK, Giri DD, Singh R, Pandey P, Gupta S, Shrivastava AK, Kumar A, Pandey KD (2013) Therapeutic and medicinal uses of *Aloe vera*: a review. *Pharmacol Pharm* 4(08):599
- Saini RK, Sivanesan I, Keum Y-S (2016) Phytochemicals of *Moringa oleifera*: a review of their nutritional, therapeutic and industrial significance. *3 Biotech* 6(2):203
- Salama RA, Mohamed MM, Elwahab MA, Shakweer MM (2016) Assessment effect of *Aloe vera*, *Azadirachta indica* and *Moringa oleifera* aqueous extracts on carbon tetrachloride-induced hepatotoxicity in rats. *Int J Pharm Pharm Sci* 8:83–89
- Sánchez E, Heredia N, Camacho-Corona MDR, García S (2013) Isolation, characterization and mode of antimicrobial action against *Vibrio cholerae* of methyl gallate isolated from *Acacia farnesiana*. *J Appl Microbiol* 115(6):1307–1316
- Sánchez M, Marchetti JM, Boulifi NE, Martínez M, Aracil J (2015) Jojoba oil biorefinery using a green catalyst. Part I: simulation of the process. *Biofuels Bioprod Biorefin* 9(2):129–138
- Sánchez M, Avhad MR, Marchetti JM, Martínez M, Aracil J (2016) Jojoba oil: a state of the art review and future prospects. *Energy Convers Manag* 129:293–304
- Sandeep G, Anitha T, Vijayalatha K, Sadasakthi A (2019) *Moringa* for nutritional security (*Moringa oleifera* lam.). *Int J Bot Stud* 4:21–24
- Sandouqa A, Al-Hamamre Z (2019) Energy analysis of biodiesel production from jojoba seed oil. *Renew Energy* 130:831–842
- Sarhan IA, Abdel-Aziz SA, Said AA, Abdel-Aleim A-AF, Awad SM (2019) Effect of dietary supplementation of extracted jojoba meal on hematology, biochemical parameters and disease

- resistance in Nile tilapia (*Oreochromis niloticus*) infected by *Aeromonas hydrophila*. *Egypt J Aquacul* 9(3):13–31
- Semenya S, Maroyi A (2012) Medicinal plants used by the Bapedi traditional healers to treat diarrhoea in the Limpopo Province, South Africa. *J Ethnopharmacol* 144(2):395–401
- Shah S, Hashmi MS (2020) Chitosan–aloe vera gel coating delays postharvest decay of mango fruit. *Hortic Environ Biotechnol*:1–11
- Shah SN, Sharma BK, Moser BR (2010) Preparation of biofuel using acetylation of jojoba fatty alcohols and assessment as a blend component in ultralow sulfur diesel fuel. *Energy Fuel* 24(5):3189–3194
- Shan TC, Matar MA, Makky EA, Ali EN (2017) The use of *Moringa oleifera* seed as a natural coagulant for wastewater treatment and heavy metals removal. *Appl Water Sci* 7(3):1369–1376. <https://doi.org/10.1007/s13201-016-0499-8>
- Sharma A, Shetty M, Parida A, Adiga S, Kamath S (2014a) Effect of ethanolic extract of *Acacia auriculiformis* leaves on learning and memory in rats. *Pharm Res* 6(3):246
- Sharma AK, Kumar A, Yadav SK, Rahal A (2014b) Studies on antimicrobial and immunomodulatory effects of hot aqueous extract of *Acacia nilotica* L. leaves against common veterinary pathogens. *J Vet Med Sci* 2014:747042
- Shokri F, Ziarati P, Mousavi Z (2016) Removal of selected heavy metals from pharmaceutical effluent by *Aloe vera* L. *Biomed Pharmacol J* 9(2):705–713
- Sivakumar D (2013) Adsorption study on municipal solid waste leachate using *Moringa oleifera* seed. *Int J Environ Sci Technol* 10(1):113–124
- Skotti E, Anastasaki E, Kanellou G, Polissiou M, Tarantilis PA (2014) Total phenolic content, antioxidant activity and toxicity of aqueous extracts from selected Greek medicinal and aromatic plants. *Ind Crop Prod* 53:46–54
- Solliman ME-D, Shehata WF, Mohasseb HAA, Aldaej MI, Al-Khateeb AA, Al-Khateeb SA, Hegazy AE, Abdel-Moneim HM (2017) Induction of biochemical active constituents of jojoba (*Simmondsia chinensis* (link) Schneider) callus affected by hormones. *J Med Plants Res* 11(2):34–42
- Sreelatha S, Jeyachitra A, Padma P (2011) Antiproliferation and induction of apoptosis by *Moringa oleifera* leaf extract on human cancer cells. *Food Chem Toxicol* 49(6):1270–1275
- Stankov S, Fidan H, Ivanova T, Stoyanova A, Damyanova S, Desyk M (2018) Chemical composition and application of flowers of false acacia (*Robinia pseudoacacia* L.). *Ukrainian Food J* 7(4):577–588
- Strubinger A, Oliveros AR, Araque MA, Guerra J (2017) Assessment of the energy recovery of *Aloe Vera* solid residues by pyrolysis and hydrothermal conversion. *Chem Eng Trans* 57:19–24
- Sturtevant D, Lu S, Zhou Z-W, Shen Y, Wang S, Song J-M, Zhong J, Burks DJ, Yang Z-Q, Yang Q-Y (2020) The genome of jojoba (*Simmondsia chinensis*): a taxonomically isolated species that directs wax ester accumulation in its seeds. *Sci Adv* 6(11):eaay3240
- Suboj P, Babykutty S, Gopi DRV, Nair RS, Srinivas P, Gopala S (2012) *Aloe emodin* inhibits colon cancer cell migration/angiogenesis by downregulating MMP-2/9, RhoB and VEGF via reduced DNA binding activity of NF- $\kappa$ B. *Eur J Pharm Sci* 45(5):581–591
- Sulaiman F, Iyiola O, Anifowoshe T, Sulaiman A, Bello O, Akinyele T, Jimoh A, Maimako R, Otohinoji D, Osemwegie O (2020) Anti-Trypanosoma and toxicity potential of the extracts of *Acacia nilotica*, *Bombax buonopozense* and *Khaya senegalensis*. *Adv Tradition Med* 20:1–8
- Sunil M, Sunitha V, Ashitha A, Neethu S, Midhun SJ, Radhakrishnan E, Jyothis M (2019a) Catechin rich butanol fraction extracted from *Acacia catechu* L.(a thirst quencher) exhibits immunostimulatory potential. *J Food Drug Anal* 27(1):195–207
- Sunil M, Sunitha V, Radhakrishnan E, Jyothis M (2019b) Immunomodulatory activities of *Acacia catechu*, a traditional thirst quencher of South India. *J Ayurveda Integr Med* 10(3):185–191
- Suriyamoorthy S, Subramaniam K, Durai SJR, Wahaab F, Chitraselvi RPE (2014) Evaluation of wound healing activity of *Acacia caesia* in rats. *Wound Med* 7:1–7
- Taffick T, Maich EG, Ferreira LD, Bica CID, Rodrigues SRS, Nachtigall SMB (2015) *Acacia* bark residues as filler in polypropylene composites. *Polímeros* 25(3):289–295

- Talmadge J, Chavez J, Jacobs L, Munger C, Chinnah T, Chow JT, Williamson D, Yates K (2004) Fractionation of Aloe vera L. inner gel, purification and molecular profiling of activity. *Int Immunopharmacol* 4(14):1757–1773
- Tang Y, Choi E-J, Han WC, Oh M, Kim J, Hwang J-Y, Park P-J, Moon S-H, Kim Y-S, Kim E-K (2017) Moringa oleifera from Cambodia ameliorates oxidative stress, hyperglycemia, and kidney dysfunction in type 2 diabetic mice. *J Med Food* 20(5):502–510
- Tasisa BY, Nemomissa S (2019) Patch enclosure and localized effects of selected Acacia species on herbaceous richness and soil properties of rangelands in Somali regional state in Ethiopia. *J Rangel Sci* 9(4):319–332
- Taweerutchana R, Lumlerdkij N, Vannasaeng S, Akaraseenont P, Sriwijitkamol A (2017, 2017) Effect of Moringa oleifera leaf capsules on glycemic control in therapy-naive type 2 diabetes patients: a randomized placebo controlled study. *Evid Based Complement Alternat Med*:6581390
- Tejas G, Umang J, Payal B, Tusharbinu D, Pravin T (2012) A panoramic view on pharmacognostic, pharmacological, nutritional, therapeutic and prophylactic values of Moringa olifera lam. *Int Res J Pharm* 3:1–7
- Thompson RJ (2008) Method and composition of a carminative herb or natural supplement to decrease the adverse effects of orlistat, and oral lipase inhibitor. Google Patents
- Tiloke C, Phulukdaree A, Chuturgoon AA (2013) The antiproliferative effect of Moringa oleifera crude aqueous leaf extract on cancerous human alveolar epithelial cells. *BMC Complement Altern Med* 13(1):226
- Ukpaka CP (2016) Development of model for bioremediation of crude oil using moringa extract. *Chem Int* 2(1):19–28
- Uphadek B, Shinkar D, Patil P, Saudagar R (2018) Moringa oleifera as a pharmaceutical excipient. *Int J Curr Pharm Res* 10:13–16
- van Wyk B-E, Wink M (2015) *Phytomedicines, herbal drugs, and poisons*. University of Chicago Press, IL, USA
- Vargas-Sánchez K, Garay-Jaramillo E, González-Reyes RE (2019) Effects of Moringa oleifera on glycaemia and insulin levels: a review of animal and human studies. *Nutrients* 11(12):2907
- Vergara-Jimenez M, Almatrafi MM, Fernandez ML (2017) Bioactive components in Moringa Oleifera leaves protect against chronic disease. *Antioxidants* 6(4):91
- Verma S, Tripathi R, Easwari T, Shukla V (2013) The medicinal plants used in hepatic dysfunction. *Int J Pharmaceut Res* 5(4):1
- Vijayasekhar V, Prasad MS, Joshi DS, Narendra K, Satya AK, Rao KS (2016) Evaluation of phytochemicals and in vitro pharmacological activity of Acacia Sinuata plant leaves. *Int J Pharm Sci Res* 7(6):2423
- Virani S, Bhatt S, Saini M, Saxena K (2016) Aloe vera attenuates gentamicin-induced nephrotoxicity in wistar albino rats: histopathological and biochemical changes. *Asian J Pharm Clin Res* 9(1):113–117
- Wang Y, Cao L, Du G (2010) Protective effects of Aloe vera extract on mitochondria of neuronal cells and rat brain. *Zhongguo Zhong yao za zhi= Zhongguo zhongyao zazhi= China journal of Chinese materia medica* 35(3):364–368
- Wang J, C-s C, Lu Y, Ding X, Zhu M, Miao C, Chen J (2018) Novel findings of anti-cancer property of propofol. *Anti-Cancer Agents Med Chem (Formerly Current Medicinal Chemistry-Anti-Cancer Agents)* 18(2):156–165
- Winters G, Otieno D, Cohen S, Bogner C, Ragowloski G, Paudel I, Klein T (2018) Tree growth and water-use in hyper-arid Acacia occurs during the hottest and driest season. *Oecologia* 188(3):695–705
- Wittmann N, Jacovelli P, Pistorius T, Ho Dac H (2018) Wind risk management in Viet nam's acacia sawlog transition policy brief. <https://doi.org/10.13140/RG.2.2.29785.57445>
- Wuthi-udomlert M, Vallisuta O (2011) In vitro effectiveness of Acacia concinna extract against dermatomycotic pathogens. *Pharm J* 3(19):69–73

- Yadav S, Tomar A, Yadav R, Yadav S (2013) Screening of antifungal proteins from plants of Cucurbitaceae family against *Fusarium oxysporum*: potential as biofungicides. *Int Res J Environ Sci* 2(6):91–96
- Yaméogo CW, Bengaly MD, Savadogo A, Nikiema PA, Traore SA (2011) Determination of chemical composition and nutritional values of *Moringa oleifera* leaves. *Pak J Nutr* 10(3):264–268
- Yang Y, Yang M, Ai F, Huang C (2017) Cardioprotective effect of Aloe vera biomacromolecules conjugated with selenium trace element on myocardial ischemia-reperfusion injury in rats. *Biol Trace Elem Res* 177(2):345–352
- Yasmeen A, Basra SMA, Ahmad R, Wahid A (2012) Performance of late sown wheat in response to foliar application of *Moringa oleifera* Lam. leaf extract. *Chilean J Agricult Res* 72(1):92–97
- Yasmeen A, Basra SMA, Wahid A, Farooq M, Nouman W, Rehman HU, Hussain N (2013) Improving drought resistance in wheat (*triticum aestivum*) by exogenous application of growth enhancers. *Int J Agric Biol* 15:1307–1312
- Young D (2019) *The backyard herbal apothecary: effective medicinal remedies using commonly found herbs & plants*. Page Street Publishing, IL, USA
- Zaffer M, Ahmad S, Sharma R, Mahajan S, Gupta A, Agnihotri RK (2014) Antibacterial activity of bark extracts of *Moringa oleifera* Lam. against some selected bacteria. *Pak J Pharm Sci* 27(6):1857–1862
- Zaku S, Emmanuel S, Tukur A, Kabir A (2015) *Moringa oleifera*: an underutilized tree in Nigeria with amazing versatility: a review. *Afr J Food Sci* 9(9):456–461
- Zeydouni G, Rodriguez Couto S, Nourmoradi H, Basiri H, Amoatey P, Esmaili S, Saeidi S, Keishams F, Mohammadi MJ, Omidi Khaniabadi Y (2020) H<sub>2</sub>SO<sub>4</sub>-modified Aloe vera leaf shells for the removal of P-chlorophenol and methylene blue from aqueous environment. *Toxin Rev* 39(1):57–67
- Zhang N, Gao T, Wang Y, Liu J, Zhang J, Yao R, Wu F (2020) Modulating cationicity of chitosan hydrogel to prevent hypertrophic scar formation during wound healing. *Int J Biol Macromol* 154:835–843. <https://doi.org/10.1016/j.ijbiomac.2020.03.161>
- Zięba M, Małysa A, Noga A (2015) Evaluation of selected quality features of creams with addition of jojoba oil designed for dry skin. *Polish J Cosmetol* 18(2):132–137
- Zuhaidi A, Vijayanathan J (2018) Phytoremediation of heavy metals using acacia mangium in rahman hydraulic tin (RHT) tailings, Klian Intan, Malaysia. *Agric Res* 8(3):247–249