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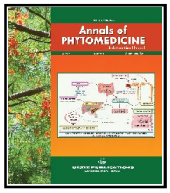

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A review on utilization of residual biomass from spices, fruits and medicinal plants for their pharmacological potential

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Abstract

This review explores the potential of residual biomass from spices, medicinal plants, and fruits. It examines its applications in agriculture, pharmaceuticals, animal nutrition, and pest management. The review also looks into the extraction of bioactive compounds and how they can address global health challenges. One interesting aspect is the utilization of spent water from essential oil industries to offer innovative solutions while also considering environmental ramifications. Looking ahead, the review outlines future prospects such as advancements in extraction techniques and biotechnological applications. Overall, the review underscores the therapeutic and economic potential of residual biomass, urging stakeholders to invest in its research and development.

1. Introduction

The world's agricultural industry produces a significant amount of residual biomass (solid, liquid, and gaseous) annually; this resource is thought to be the most abundant, profitable, and renewable one on the planet. If , they are not recycled in an environmentally sustainable manner, many of these leftovers are regarded as environmental liabilities. Any biological substance that is not purposefully produced during a production process is referred to as residual biomass. According to Olofsson and Börjesson (2018), residual biomass is produced as a byproduct that might or might not be garbage. Straw, for instance, is a byproduct of the manufacturing of oil and tiny grains (Goodman, 2020). Oil cakes, on the other hand, are leftovers from the edible oil sector. Since they do not add more carbon dioxide to the environment, these residual biomasses are regarded as carbon neutral (Jain and Naik, 2018). Reusing leftover biomass from the medicinal and aromatic plant sector is crucial to preventing environmental effects, extracting phytochemicals, and converting it into valuable products, promoting financial gain and sustainability (Oleszek *et al.*, 2019). It reveals that agricultural and industrial sectors produce residues from aromatic plants, including distillation residues and leftover fractions. Some parts are used in pharmaceuticals, while others go unused. The manufacture of natural bioactive chemicals from these residues is a growing demand, but requires careful planning and execution (Eden *et al.*, 2017).

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A significant amount of biomass is produced as a byproduct of steam and hydrodistilling aromatic plants for essential oil. Therefore, the vast amounts of biomass waste from distillation that are produced from aromatic plants are left unused. The grower of aromatic plants may therefore be able to make additional money through the efficient recycling of these leftover biomasses (Marcelino *et al.*, 2023). This review discusses the management of leftover biomass from medicinal spices and herbs and fruits including its use in crop protection, industrial extraction of bioactive chemicals and its pharmacological activities. It highlights the potential for eco-friendly and profitable disposal of biomass, highlighting its potential in medicinal, cosmetic, and fragrance goods.

2. Medicinal and aromatic plants for health and well-being

A Medicinal Plants Board has been constituted to address these issues. India and China are the two major producers of these plants, with 40% of global biodiversity and rare species availability (Table 1). Over 95% of plants used by the herbal or pharmaceutical industry are collected from wild sources (Chowti *et al.*, 2018). *Bacopa monnieri* is a medicinal plant used to treat neurodegenerative disorders, with its neuroprotective effect attributed to bacoside A, a phytoconstituent that inhibits amyloid protein aggregation in Alzheimer's patients (Rao *et al.*, 2012). Withaferin A, a steroidal lactone from the *Withania somnifera* plant, prevents ethanol withdrawal in rats during alcohol dependence phase. It reduces elevated somatic behaviors, hyperlocomotion, depressive behavior, and anxiety in SD rats, and attenuates elevated plasma corticosterone and ACTH levels (Bharathi *et al.*, 2021). We need to conserve and develop medicinal plant genetic resources and their cultural roots in diverse agroecosystems. Aromatic and medicinal plants like Patchouli, Stevia, Citronella, Cinnamon are grown in mild tropical

areas, while geranium, texus, ginseng, saffron, *etc*., can be cultivated in temperate and alpine zones. Mizoram is known for its exotic orchids and medicinal plants. Curcuma species have several medicinal properties that make them effective against various diseases (Naikodi *et al.*, 2021). Medicinal and aromatic plants offer herbal medications and health products. Despite using some parts of these plants, such as the fruit, root, leaf, and flower, a vast amount of biomass from other parts of the same plant goes unused and becomes waste (Vasanthkumar, 2023). As there is a high demand for natural bioactive compounds.

Table 1: Major medicinal and aromatic crops and their pharmacological activities

Medicinal uses	Name of plant	Pharmacological activities	References
Skin			
Antiseptics	*Avena sativa* L.	Disinfects the skin	Singh *et al.*, 2013
Antibiotic	*Curucuma longa*	Protects the skin	Sivakumar *et al.*, 2022
Respiratory system			
Antiseptics and antibiotics	*Centella asiatica*	Helps the lungs resist infection	Arribas-López *et al.*, 2022
Musculo-skeletal system			
Antispasmodics	Cinchona (*Cinchona* spp.)	Relax tense and cramped muscles	Aslam *et al.*, 2023
Nervous system			
Nervine	*Rosemary (Rosemarinus officinalis)*	Strengthen the nerve	Selvaraj *et al.*, 2022
Circulation and heart			
Circulatory simulants	Cayenne (*Capsicum frutescens*)	Improves the circulation of blood to the impurities	Maya *et al.*, 2021
Digestive organs			
Antiseptics	Ginger *(Zingiber officinalis)*	Protects against infection	Rani *et al.*, 2023
Astringents	Bistort *(Polygonum bistorta)*	Tighten up the inner lining of the intestines and create a protective coating over them	Mezerji *et al.*, 2023
Bitters	Wormwood *(Artemisia absinthum)*	Stimulate secretion of digestive juices by the stomach and intestines	Ahamad, 2019
Carminaties	Sweet flag *(Acorus calamus)*	Relieve wind and griping pain	Raj *et al.*, 2023

3. Residual biomass from medicinal and aromatic plants for sustainable applications

In recent years, there has been a growing focus on reducing waste production and enhancing the economic value of waste derived from MAPs (Lubbe and Verpoorte, 2011). Waste can be managed using techniques such as enzymes, compost, biochar, biogas, and biopesticides. Vermicompost, made from MAP waste, is an organic fertilizer that improves soil health and fertility while reducing the need for chemical fertilizers. It offers financial benefits for farmers (Saha and Basak, 2020). The increasing need for natural bioactive substances has led to a steady increase in the industrial use of aromatic and medicinal plants. To keep up with the increasing demand, MAP cultivation in India has grown dramatically from 131,000 ha in 2004-2005 to 687000 ha in 2018 - 2019. The market has priceless herbal goods made from medicinal plants. Current management aims to minimize environmental impact and maximize residual biomass. Waste from distilling mentha, lemon grass, and palmarosa can absorb heavy metals and colors (Pandey *et al.*, 2019). Residual biomass from medicinal and aromatic plants (MAPs) can generate significant biomass. For example, the root of plants like ginseng and ashwagandha is a lucrative source of bioactive compounds. Similarly, the above-ground parts of the ashwagandha plant are a major source of bioactive compounds (Namdeo and Ingawale, 2021; Ratan *et al.*, 2021). *Aloe vera* roots have medicinal potential due to their quinone content. Isabgol residue can be used for compost, biochar or cattle feed (Maqbool *et al.*, 2023).

4. Bioactive and phytochemicals from residual biomass of spices and herbs

Pepper, scientifically known as *Piper nigrum* L., contains piperine in its fruit, which is noted for its ability to reduce insulin resistance, exert anti-inflammatory effects, and improve hepatic steatosis. Cardamom, available in both small (*Elettaria cardamomum* L.) and large (*Amomum subulatum* Roxb.) varieties, contains cineole, limonene, and a-terpinyl acetate in its fruit, offering benefits such as abortifacient, laxative, and carminative properties, as well as relief in various conditions including asthma, bronchitis, and scabies. Turmeric, scientifically known as *C. longa* boasts curcuminoids and curcumin in its fruit, which contribute to its diverse medicinal properties such as being anti-inflammatory, antihepatotoxic, antimicrobial, and antioxidant Ginger (*Z. officinale*), primarily found in its rhizome, contains gingerols, shogaols and paradols, which confer

respiratory protective, antiobesity, antidiabetic, and antiemetic activities. Chilli, also known as *C. frutescens* L., is characterized by phenols and vitamin C in its rhizome, offering benefits such as heart disease prevention, weight loss promotion, and reduction in sickness duration. Coriander (*Coriandrum sativum* L.) contains p-cymene, alpha-pinene, camphor, geraniol, and limonene in its leaf and seed parts, which collectively lower blood sugar, prevent cellular damage, aid digestion, and improve memory. Fennel (*Foeniculum vulgare*, Miller) is rich in essential oil and anethole in its fruit, providing support for healthy skin, anti-inflammatory effects, and relief from anemia symptoms. Cumin (*Cuminum cyminum* L.) contains cuminaldehyde in its fruit, offering benefits such as anticancer properties, blood sugar control, and anti-inflammatory effects. Fenugreek (*Trigonella foenum-graecum* L.) features graecunins, fenugreek B, and trigofoenosides in its seeds, which reduce diabetes risk, aid weight loss, and alleviate inflammation. Aniseed (*Pimpinella anisum* L.) contains anethole and 4-anisaldehyde in its fruit, potentially reducing symptoms of depression and protecting against stomach ulcers. Celery (*Apium graveolens* L.) contains apiin and apigenin in its fruit, offering potential benefits in cancer prevention, blood pressure management, and Alzheimer's disease prevention. Cinnamon (*Cinnamomum zeylanicum* Blume) bark is rich in cinnamaldehyde and eugenol, exhibiting antiviral, antibacterial, and antifungal properties, along with effects on blood pressure and blood sugar reduction. Caraway (*Carum carvi* L.) fruit contains carvacrol, carvone, and other compounds, used traditionally for digestive issues like heartburn and bloating. Dill (*Anethum graveolens* L.) contains carvone, a-phellandrene, and limonene, showing hypolipidemic and hypoglycemic effects. Bishop's weed (*Trachyspermum ammi* L.) fruit contains methoxsalen and is used for digestive disorders, asthma, chest pain, kidney stones, and fluid retention. Mustard (*Brassica juncea* L.) seeds feature phenols, flavonoids, glucosinolates, and carotenoids, offering protection against cancer, diabetes, psoriasis, and contact dermatitis. Kokam (*Garcinia indica* Choisy) fruit is rich in vitamins, minerals, stearic acid, and oleic acid, supporting immunity, weight management, intestinal health, and cancer risk reduction. Garlic (*Allium sativum* L.) bulb contains allicin, known for its blood pressure-lowering and anti-inflammatory properties, as well as immune support. Mint (*Mentha piperita* L.) leaf contains menthol, menthofuran, and 1,8-cineol, aiding in irritable bowel syndrome relief, indigestion, and improved brain function. Curry leaf (*Murraya koenigii* L.) leaf contains linalool, elemol, geranyl acetate, and other compounds, offering benefits in dysentery, diarrhea, diabetes, morning sickness, and nausea. Cassia (*Cinnamomum aromaticum* Nees) bark contains cinnamaldehyde and is used for conditions like erectile dysfunction, hernia, joint pain, and menopausal symptoms. Greater galanga (*Alpinia galanga* L.) rhizome contains 1,8-cineol, a-fenchyl acetate, b-farnesene, and other compounds, providing benefits in male fertility, inflammation reduction, heart health, muscle relaxation, and cold prevention. Vanilla (*Vanilla fragrans* Ames) pod contains vanillin, which may offer antioxidant effects and possess potential anti-inflammatory properties, benefiting brain health and aiding in reducing added sugar intake. Pepper long (*Piper longum* L.) fruit, rich in piperine, is known to improve appetite and digestion, along with treating various digestive issues like stomachache, heartburn, indigestion, intestinal gas, diarrhea, and cholera. Saffron (*Crocus sativus* L.) stigma contains safranal, anthocyanin, and carotenoids, exhibiting potential benefits in reducing PMS symptoms, acting as an aphrodisiac, and improving eyesight in adults with age-related macular degeneration (AMD). Parsley (*Petroselinum crispum*) seed contains myristicin and apiole, which may help manage diabetes, improve brain health, and promote heart health. Sweet flag (*Acorus calamus*) rhizome, rich in asarones, aids in clarity of voice, treats stomach disorders, and effectively cures asthma. Star anise (*Illicium verum* Hooker) fruit, containing flavonoids and anethole, helps improve digestion, alleviate cramps, and reduce nausea. Tejpat (*Cinnamomum tamala* Nees) leaf, with its components like cinnamaldehyde and linalool, possesses anticancer, anti-inflammatory, and antibacterial properties. Pomegranate (*Punica granatum* L.) seed, rich in elagitannin, punicalagin, and ellagic acid, helps prevent cancer, cardiovascular disease, osteoarthritis, and rheumatoid arthritis. Marjoram (*Marjorana hortensis*) leaf, containing rosmarinic acid, sinapic acid, vanillic acid, and ferulic acid, exhibits anti-inflammatory, antimicrobial, and antioxidant properties. Bay leaf (*Laurus nobilis* L.) leaf contains eucalyptol, terpinyl acetate, and methyleugenol, aiding in treating type 2 diabetes and reducing hyperglycemia and hyperinsulinemia (Pooja *et al.*, 2023). Hyssop (*Hyssopus officinalis* L.) leaf, rich in luteolin, diosmin, quercetin, and apigenin, is used for various digestive and intestinal problems, including liver and gallbladder conditions, intestinal pain, gas, colic, and loss of appetite. Asafoetida (*Ferula asafoetida* L.) resin, with its components like asaresinotannols A and B, ferulic acid, and umbelliferone, exhibits antibacterial, antifungal, and antimicrobial effects, along with potential anticancer properties and brain health protection. Caper (*Capparis spinosa* L.) fruit, containing rutin, offers antioxidant powers, mineral and vitamin vitality, and fiber-rich benefits. Horseradish (*Armoracia rusticana* Gaertner) rhizome, rich in allyl isothiocyanate, may prevent cancer, strengthen the immune system, and treat urinary tract and sinus infections. Lovage (*Levisticum officinale* Koch) leaf, containing phthalides and terpenoids, fights the risk of kidney stones, supports lung health, soothes rough spots, promotes healthy skin, and combats harmful organisms. Juniper berry (*Juniperus communis* L.) berry, with components like myrcene, sabinene, limonene, and b-pinene, improves skin conditions, may aid digestion, and could help treat leishmaniasis (Rani *et al.*, 2023).

5. Bioactive and phytochemicals from residual biomass of medicinal and aromatic plants

Phytochemical research on medicinal plants has primarily focused on roots, leaves, and stems, neglecting the potential of extracting compounds from residual biomass. Ashwagandha, a well-known medicinal plant, contains withanolides and alkaloids in its roots. Recent studies have shown that leaves contain anticancer therapeutic compounds withanolides, bioactive withanamides as potential antioxidants, and protective effects against beta-amyloid-induced cytotoxicity, The highest withaferin-A (WA) accumulation was found in leaves, followed by 12-deoxywithastramonolide (WO) and withanolide-A (WD) in roots. The concentrations were higher in fruits, stems, and roots (Ahmed *et al.*, 2018; Gajbhiye *et al.*, 2015). Innovative recycling approaches, such as the regeneration of artemisinin from artemisinic acid, can increase phytochemical production while mitigating waste generation, minimizing environmental impact and contributing to sustainable raw material utilization (Lapkin *et al.*, 2006).

6. Bioactive and phytochemicals from residual biomass of fruits

A study on *Psidium guajava*, also known as guava, found that the tannin-rich fraction of the plant has remarkable wound healing properties. The study found no cytotoxicity, but the tannin-rich fraction at 100 µg/ml showed the highest cell proliferation and migration of 62.48% after 24 h of exposure, supporting the plant's traditional claims as a potential wound healing plant (Jayakumari *et al.*, 2023). The study found that chitosan, gum tragacanth, *A. vera*, and oxalic acid coatings significantly increased guava fruit storage shelf life and reduced weight loss. Chitosan coatings showed the lowest weight loss and enhanced firmness. Gum tragacanth and *A. vera* coatings had favorable acceptability ratings. Chitosan coatings also reduced polygalacturonase activity, suggesting they preserve fruit texture and inhibit decay (Sharma *et al.,* 2023). The study examines the antimicrobial properties of *Haldina cordifolia* and *Thevetia peruviana* leaf extracts against multidrug-resistant strains using the well diffusion method. Results show both extracts have bactericidal effects, with *T. peruviana* extract showing better effects. The growth curve assay showed significant effects on *Acinetobacter baumannii* and *Pseudomonas aeruginosa* (Dash *et al.*, 2023). Several fruits have been studied for their anti-inflammatory properties. Grape (*Vitis* spp.) seeds contain a procyanindin extract that inhibits the overproduction of nitric oxide (NO) and prostaglandin E2 (PGE2). Strawberry (*Fragaria ananassa*) and mulberry (*Morus alba*) fruit juice ethanol extracts have been shown to decrease the secretion ratio of splenocytes' cytokines, including interferon-gamma (IFN-g), interleukin-2 (IL-2), interleukin-12 (IL-12), and interleukin-10 (IL-10). Citrus peel extract from *Citrus sinensis* reduces the release of tumor necrosis factor-alpha (TNF-a) and NO Ethyl acetate extract from Chinese pear (*Pyrus pyrifolia*) exhibits inhibition of edema formation 0.5-5 h after edema induction. Polyphenols found in blueberry (*Vaccinium* sect. *cyanococcus*) inhibit the production of NO, interleukin-1beta (IL-1b), and TNF-α. Pomegranate (*Punica granatum*) contains compounds such as punicalagin, punicalin, strictinin A, and granatin B, which reduce the production of NO and PGE2. Narirutin from *Citrus sinensis* inhibits the release of NO, PGE2, IL-1b, and TNF-α. Acai fruit (*Euterpe oleracea*) containing flavone velutin demonstrates excellent anti-inflammatory capacity. Kaffir lime (*Citrus hystrix*) exhibits higher anti-inflammatory activity due to its monogalactosyldiacylglycerol content (Sangeeta *et al.*, 2023).

7. Utilization of spent water from the essential oil industry

Hydrosol, or spent water, is a fragrant liquid waste produced during the extraction of essential oils from herbs. It contains valuable oil along with cellulose, hemicellulose, and lignin (Srivastava *et al.*, 2021). Basil and rosemary are rich in rosmarinic acid and caffeic acid. Aromatic plant hydrosols have antifungal and antibacterial properties. Essential oils are obtained through steam or hydrodistillation of fresh aromatic herbs, which results in wasted water called hydrosol. The hydrosol may contain a significant amount of the precious oil and retain its pleasant fragrance. According to Slavov *et al.* (2017), hydrosols of rose and other plants that produce essential oils contain beneficial bioactive substances. Rosmarinic acid is present in high-value hydrosol of rosemary. Fresh herbs like sage, basil, and rosemary can be distilled to produce a hydrosol that has many water-soluble phenolic compounds, including rosmarinic acid. Aromatic plant hydrosols may have antibacterial and antifungal properties. According to Pontes *et al.* (2019), the main components of rose oil such as citronellol and geraniol have a potent antibacterial activity. Therefore, incorporating rose water as an ingredient in cosmetic products can not only provide a pleasant fragrance but also offer significant socio-economic benefits.

8. Utilizing residual biomass from medicinal and aromatic plants as livestock nutrition

Medicinal and aromatic plant waste is rich in fiber components such as cellulose, hemicellulose, lignin, and silica, as well as crude protein, making it an excellent byproduct for animal feed (Saha and Basak, 2020). Ginseng meal enhances milk production and quality in dairy calves, and promotes the growth rate of chicks. Dehusked isabgol seeds are used as cattle feed in India due to their high content of protein, starch, and fatty acids. Residues from medicinal and aromatic plants contain bioactive and nutraceutical compounds, making them suitable for animal feed. Ginseng meal is rich in fiber and protein, containing up to 16% of protein. Abdallah *et al.* (2019) have shown that incorporating ginseng meal into animal diets increases milk yield and quality in dairy cattle and promotes the growth rate of chicks. Similarly, the main product of isabgol, psyllium husk, recovered during the dehusking process, is rich in starch, protein (17-19%), and fatty acids, making it suitable for cattle feed in India.

9. Biopesticides

Chemical pesticide overuse causes environmental and health issues, leading to pesticide-resistant populations. Biopesticides and biopesticides are being explored, with essential oil distillation residues showing stronger pesticidal properties against crop pests (Maurya *et al.*, 2022). Plant residues and hydrosols have shown pesticidal activity against crop pests. *Rosemary officinalis*, lavandin, and cotton lavender residues have potent antifeedant activity against Colorado potato beetle, while *Mentha suaveolens* and *M. pulegium* hydrosols exhibit strong insecticidal properties against *Toxoptera aurantii*. Sweet basil and rue hydrosols affect the mortality and fecundity of crop pests like *Aphis gossypii* and *Tetranychus urticae*, while *Origanum majorana* and *Drimys winteri* hydrosols have shown promising activity against the green peach aphid and *Aegorhinus superciliosus*, respectively. Further research is needed to understand the bioactive components and synergistic effects of these plant residues and hydrosols for effective pest management strategies.

10. Future prospects

Residual biomass from plants and fruits can be utilized to solve global health, environmental, and socioeconomic issues. Research can focus on advanced extraction techniques, biotechnology, functional food, pharmaceuticals, sustainable agriculture, biofuels, and policy implications. Advanced extraction techniques can optimize the process and reduce environmental impact. Biotechnology can help produce high-value bioactive compounds from plant biomass. Derived compounds can be developed into novel pharmaceutical drugs. Sustainable agriculture and waste management can be achieved by reusing residues and byproducts. Future directions could involve investigating novel extraction methods, such as utilizing green solvents or employing advanced biotechnological approaches like enzymatic processes.

11. Conclusion

The review highlights the significant potential of utilizing residual biomass from spices, medicinal plants, and fruits to address environmental challenges and promote sustainable development. Key findings include the ability to extract bioactive compounds from these sources, leading to the creation of value-added products beneficial across multiple sectors such as agriculture, pharmaceuticals, and animal nutrition. This not only improves human health but also reduces waste generation and minimizes environmental impact. Moving forward, further research is essential to optimize extraction techniques and explore biotechnological applications, ultimately maximizing resource utilization and reducing energy consumption. Additionally, there is a need to evaluate the scalability and economic viability of these techniques to ensure their practicality for widespread implementation. Collaborative efforts between academia, industry, and policymakers will be crucial in driving forward these research agendas and realizing the full potential of residual biomass utilization for sustainable development.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

References

Abdallah, A.; Zhang, P.; Zhong, Q. and Sun, Z. (2019). Application of traditional Chinese herbal medicine by-products as dietary feed supplements and antibiotic replacements in animal production. Current Drug Metabolism, **20**(1):54-64.

Ahamad, J. (2019). A pharmacognostic review on *Artemisia absinthium*. International Research Journal of Pharmacy, **10**(1):25-31.

Ahmed, W.; Mofed, D.; Zekri, A.R.; El-Sayed, N.; Rahouma, M. and Sabet, S. (2018). Antioxidant activity and apoptotic induction as mechanisms of action of *Withania somnifera* (Ashwagandha) against a hepatocellular carcinoma cell line. Journal of International Medical Research, **46**(4):1358-1369.

Arribas López, E.; Zand, N.; Ojo, O.; Snowden, M. J. and Kochhar, T. (2022). A systematic review of the effect of *Centella asiatica* on wound healing. International Journal of Environmental Research and Public Health, **19**(6):3266.

Aslam, S.; Jabeen, T.; Ahmad, M. and AL Huqail, A. A. (2023). Cinchona. In Essentials of Medicinal and Aromatic Crops, pp:221-248.

Bharathi, G. S.; Lalitha, V.; Sethumathi, P.; Sivakumar, T.; Selvi, P.; Kavitha, M. and Kumar, R. N. (2021). Plants and their derivatives as potential source in treatment of alcohol withdrawal syndrome and other treatment strategies: A review. Ann. Phytomed., **10**(2):36-43.

Chowti, S. P.; Rudrapur, S. and Naik, B. (2018). Production scenario of medicinal and aromatic crops in India. Journal of Pharmacognosy and Phytochemistry, **7**(3S):274-277.

Dash, P. P.; Kumar, S.; Mishra, A. and Srivastava, S. (2023). Antimicrobial activity of *Haldina cordifolia* (Roxb.) Ridsdale and *Thevetia peruviana* (Pers.) Schum. leaf extract against multidrug resistant microbes. Ann. Phytomed., **12**(1):1-9.

Eden, M.; Gerke, H.H. and Houot, S. (2017). Organic waste recycling in agriculture and related effects on soil water retention and plant available water: a review. Agronomy for Sustainable Development, **37**:1-21.

Gajbhiye, N.A.; Makasana, J. and Kumar, S. (2015). Accumulation of three important bioactive compounds in different plant parts of *Withania somnifera* and its determination by the LC–ESI-MS-MS (MRM) method. Journal of Chromatographic Science, **53**(10):1749-1756. https://doi.org/10.1093/chromsci/bmv088

Goodman, B. A. (2020). Utilization of waste straw and husks from rice production: A review. Journal of Bioresources and Bioproducts, **5**(3):143-162.

Jain, R. and Naik, S. (2018). Adding value to the oil cake as a waste from oil processing industry: Production of lipase in solid state fermentation. Biocatalysis and Agricultural Biotechnology, **15**:181-184.

Jayakumari, S.;Vijayalakshmi, A.;Anandhi, N.;Mounisha, B.;Sameer, M. M. and Yogeshwaran, V. (2023). Wound healing and cytotoxic effects of tannin rich fraction of *Psidium guajava* L. leaves. Ann. Phytomed., **12**(2):1-6.

Lapkin, A. A.; Plucinski, P. K. and Cutler, M. (2006). Comparative assessment of technologies for extraction of artemisinin. Journal of Natural Products, **69**(11):1653-1664.

Lubbe, A. and Verpoorte, R. (2011). Cultivation of medicinal and aromatic plants for specialty industrial materials. Industrial Crops and Products, **34**(1):785-801.

Maqbool, Z.; Yousaf, Z.; Aftab, A.; Shahzadi, Z. and Gohar, U. F. (2023). Isabgol. In: Essentials of Medicinal and Aromatic Crops. pp:709-733.

Marcelino, S.; Gaspar, P. D. and Paço, A. (2023). Sustainable waste management in the production of medicinal and aromatic plants: A systematic review. Sustainability, **15**(18):13333.

Maurya, P.; Mazeed, A.; Kumar, D.; Ahmad, I. Z. and Suryavanshi, P. (2022). Medicinal and aromatic plants as an emerging source of bioherbicides. Current Science, pp:258-266.

Maya, M.; Ananthi, V.; Arun, A.; Kumar, P.; Govarthanan, M.; Rameshkumar, K.; Veeramanikandan, V. and Balaji, P. (2021). Protective efficacy of Capsicum frutescens fruits in pancreatic, hepatic and renal cell injury and their attenuation of oxidative stress in diabetic Wistar rats. Journal of Taibah University for Science, **15**(1):1232-1243.

Mezerji, Z. K.; Boshrouyeh, R.; Razavi, S. H.; Ghajari, S.; Hajiha, H.; Shafaei, N.; Karimi, E. and Oskoueian, E. (2023). Encapsulation of *Polygonum bistorta* root phenolic compounds as a novel phytobiotic and its protective effects in the mouse model of enteropathogenic *Escherichia coli* infection. BMC Complementary Medicine and Therapies, **23**(1):49.

Naikodi, M. A. R.; Chaithra, D.; Venkatesham, B.; Siddiqui, J. I. and Husain, M. (2021). Phytonanotechnological perspectives and biological activities in Curcuma species. Ann. Phytomed., **10**(2):82-89.

Namdeo, A. G. and Ingawale, D. K. (2021). Ashwagandha: Advances in plant biotechnological approaches for propagation and production of bioactive compounds. Journal of Ethnopharmacology, **271**:113709.

Oleszek, M.; Kowalska, I. and Oleszek, W. (2019). Phytochemicals in bioenergy crops. Phytochemistry Reviews, **18**:893-927.

Olofsson, J. and Börjesson, P. (2018). Residual biomass as resource: Life-cycle environmental impact of wastes in circular resource systems. Journal of Cleaner Production, **196**:997-1006.

Pandey, V. C.; Rai, A. and Korstad, J. (2019). Aromatic crops in phytoremediation: From contaminated to waste dumpsites. In Phytomanagement of Polluted Sites. pp:255-275. Elsevier.

Pontes, E. K. U.; Melo, H. M.; Nogueira, J. W.A.; Firmino, N. C. S.; De Carvalho, M. G;Catunda Júnior, F. E. A.and Cavalcante, T. T. A. (2019). Antibiofilm activity of the essential oil of citronella (*Cymbopogon nardus*) and its major component, geraniol, on the bacterial biofilms of *Staphylococcus aureus*. Food Science and Biotechnology, **28**(3):633-639.

Pooja, U.K; Vasanthkumar, S.S. and Prathiksha, S. (2023). Biological active compounds in herbs and Spices., pp:1-14.

Raj, A. S.; Govardhan Sahani, F. M.; Allam, R.; Sadik, M. and Prakash, A. (2023). Ayurvedic approach towards the complication of dengue in India. Ann. Phytomed., **12**(2):102-110.

Rani, J.; Kaur, P. and Chuwa, C. (2023). Nutritional benefits of herbs and spices to the human beings. Ann. Phytomed., **12**(1):187-197.

Rao, S.; Rajkumar, P.; Kaviraj, C. and Parveen, P. A. (2012). Efficient plant regeneration from leaf explants of *Bacopa monniera* (L.) Wettst.: A threatened medicinal herb. Ann Phytomed, **1**:110-117.

Ratan, Z. A.; Haidere, M. F.; Hong, Y. H.; Park, S. H.; Lee, J.O.; Lee, J. and Cho, J. Y. (2021). Pharmacological potential of ginseng and its major component ginsenosides. Journal of Ginseng Research, **45**(2):199-210.

Saha, A. and Basak, B. (2020). Scope of value addition and utilization of residual biomass from medicinal and aromatic plants. Industrial Crops and Products, **145**:111979.

Sangeeta, S.; Chandola, G.; Ramachandran, P.; Yadav, P. and Rai, S. (2023). Fruits that heal: A natural boon to cure colon diseases. Ann. Phytomed., **12**(1):1-10.

Selvaraj, K.; Sivakumar, P.; Shalom, S. V.; Bharathi, A.; Velayutham, A. and Prabha, T. (2022). A review on the *in vitro* regeneration of the timeless panacean medicinal and aromatic herb: *Rosmarinus officinalis* (L.). Ann. Phytomed., **11**(1):247-252.

Sharma, K.; Ravi, K. and Wani, A. W. (2023). Evaluation of natural edible coatings for enhancing the post-harvest quality and shelf-life of guava (*Psidium guajava* L.) fruits. Ann. Phytomed., **12**(1):808-815.

Singh, R.; De, S. and Belkheir, A. (2013). *Avena sativa* (Oat), a potential neutraceutical and therapeutic agent: An overview. Critical Reviews in Food Science and Nutrition, **53**(2):126-144.

Sivakumar, P.; Monisha, S.; Selvaraj, K. V.; Chitra, M.; Prabha, T.; Santhakumar, M.; Bharathi, A. and Velayutham, A. (2022). Nutritional value, phytochemistry, pharmacological and *in vitro* regeneration of turmeric (*Curcuma longa* L.): An updated review. Ann. Phytomed., **11**(1):236-246.

Slavov, A.; Vasileva, I.; Stefanov, L. and Stoyanova, A. (2017). Valorization of wastes from the rose oil industry. Reviews in Environmental Science and Bio. Technology, **16**:309-325.

Srivastava, N.; Shrivastav, A.; Singh, R.; Abohashrh, M.; Srivastava, K.; Irfan, S.; Srivastava, M.; Mishra, P.; Gupta, V. K. and Thakur, V. K. (2021). Advances in the structural composition of biomass: fundamental and bioenergy applications. Journal of Renewable Materials, **9**(4):615-636.

Vasanthkumar, S.S (2023). Medicinal plants in traditional and modern folk medicine. Reviews pp:138-155.

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