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Valorization of medicinal and aromatic plants waste: Review article

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Abstract
India being an agriculture-based country generates lots of waste from agricultural farming and agro-processing industries. Agro and industrial waste particularly from medicinal and aromatic plants generate various solid wastes viz. distilled waste of various aromatic crops and the non-utilized parts of medicinal plants. The increasing demand for natural resources requires careful planning and highlights the value of using plant wastes as a new resource. On the other hand, India produced more than 6.0 million tons per annum of aromatic spent biomass, and waste disposal is a major problem in India. Thus, the huge amounts of wastes that are produced are either burnt by growers or remain in a field that causes environmental pollution and their disposal is becoming a concern. The way of managing the situation is to reduce the losses of biomass and to utilize the available material for the production of value-added products. The waste could be used for the production of fertilizers, fuel, value-added products through processing, extraction, hydrolysis or fermentation and as animal feed. The utilization of waste will not only economize the cost of finished products but also reduce the pollution level.

Keywords: valorization, spent biomass, vermicompost, biochar, antimicrobial

1. Introduction

India being an agriculturally based country generates lots of waste from agricultural farming and agro processing industries. Waste disposal is major problem in India. In the era of globalization environmental issues related with waste disposal is also a hot topic at present. Huge quantity of waste is either burnt or remain in field which causes environmental pollution like Co_2 emission, atmosphere pollution. One way of managing the situation is to reduce the losses and the other is to utilize the available material for the production of value-added products. Residual biomass is any biological substance that is not produced on purpose during a manufacturing process. As a result, Olofsson and Börjesson (2018) describe residual biomass as a waste.

Medicinal and aromatic plants have a significant part in people's health and well-being since they provide a variety of herbal medications and healthcare goods. Based on the constant uses of the particular parts of both the medicinal and aromatic plants viz., fruit, root, leaf, flower etc. A vast biomass of other part of the same plant remains unutilized in the various Ayurvedic and traditional therapeutic medicines, and hence becomes waste. As there is a high demand for natural bioactive compounds (Santana *et al.*, 2012) [49], the area under cultivation of medicinal and aromatic plants in India has extended from 1,31,000 ha in 2004-2005 to 6,87,000 ha in 2018–2019. (Anonymous, 2019). According to sources, production increased from 1,59,000 metric tonnes in 2004–05 to 8,46,000 MT in 2018–2019. (Anonymous, 2019). At the moment, both society and industry is continually taking steps to minimize the load of residues by valorizing them (Galanakis, 2015) [34].

Valorization is the process of increasing both the current and original value of something. Waste valorization is the process of transforming waste materials into valuable goods such as materials, chemicals, fuels, or other sources of energy by reusing, recycling, or composting them. India, on the other hand, is said to produce over 6.0 million tonnes of aromatic waste biomass each year. These aromatic crops contain 2-3% (w/w) of essential oil. After essential oil extraction using steam or hydro distillation processes, the unwanted biomass is treated as waste material. Even though statistics on medicinal plant wastes have yet to be reported, it is estimated that each year around 20 million tonnes of dry biomass are generated worldwide from aromatic plants. Though there has been a huge amount of agro and industrial waste recorded from medicinal plants.

The waste utilization will not only be economizing the cost of finished products but also reduce the pollution level. The waste could be used for the production of fertilizers, fuel, and value-added products through processing, extraction, hydrolysis or fermentation and as animal feed. The present review work will examine how unwanted biomass from MAPs is managed and how it is used to separate phytochemicals and convert phenolics-antioxidants into a variety of value-added products like compost, charcoal, biogas, enzymes, and bio pesticides. It will also include the use of waste biomass as a bio-sorbent for waste water and other industrial effluent treatment, as well as the industrial application of waste biomass for isolating bioactive chemicals for usage in pharmaceutical, cosmetic, and fragrance goods.

2. Various uses of Medicinal and aromatic plant waste

2.1 Bioactive phytochemicals from MAPs residual biomass

Phytochemical research has traditionally focused on recognized parts of medicinal and aromatic plants, with little attention paid to phytochemical extraction from underutilized parts. Recent studies on the extraction of bioactive phytochemicals from unused parts of some medicinal and aromatic plants has gain some popularity. The anti-cancer therapeutic chemicals withanolides are also found in the leaves of Ashwagandha (*Withania somnifera* L Dunal), which have comparable phytochemical contents to the roots. (Jayaprakasam *et al.*, 2003; Gajbhiye *et al.*, 2015) [30, 23]. W. *somnifera's* bioactive withanamides are antioxidants with a protective action against beta-amyloid-induced cytotoxicity, which has been linked to Alzheimer's disease (Jayaprakasam *et al*., 2003) [30]. Bolleddula *et al*., (2012) [12] found 62 secondary metabolites with a new structure of withanamides and withanolides from *W. somnifera* fruits using HRMS and HRMS/MS techniques based on mass spectral data.

Apart from bioactive phytochemicals, the search for new natural antioxidants has accelerated dramatically. The phenolics and antioxidants found in the biomass of several aromatic plants have long been recognized (Parejo *et al.*, 2002; Torras-Claveria *et al.*, 2007) [40]. Because of their low cost and environmental friendliness, residues will be an excellent alternative supply of antioxidants (Rached *et al.*, 2018; Bistgani *et al.*, 2019) [42, 10]. Some aromatic plant decoction fluids have antioxidant and antiradical properties, according to studies (Albano *et al.*, 2012) [1]. Lactones made from Lavandula straw, like herniarin and coumarin, have antispasmodic and anti-inflammatory properties (Tiliacos *et al.*, 2008) [59]. Despite the fact that the distilled by-products have lower antioxidant activity than the parent plant, significant amounts of antioxidants can be recovered (Saha and Basak, 2019) [46].

2.2 Spent water of essential oil industry

Spent water is also known as hydrosol, a pleasant-smelling liquid that may contain a significant amount of valuable oil. It also contains compounds like alcohol, ketone, phenol, ester, and methyl ether, among others (Inouye *et al.*, 2008) [27]. After steam or hydro-distillation is used to extract essential oils from fresh aromatic and medicinal herbs, a substantial amount of wasted water is created as a liquid waste. Aromatic waste biomass contains cellulose (35–40%), hemicellulose (25–30%), and lignin (15–20%) in large quantities. Rout *et al.* (2015) [45] are a group of researchers who came up with an innovative way to solve a problem. According to Celano *et al.* (2017) [15], hydrosol derived from distillation of fresh fragrant herbs such as sage, caffeic acid and flavonoid glycosides are prevalent in basil and rosemary, with rosmarinic acid being the most abundant. Aromatic plant hydrosols have been shown in several investigations to have antifungal and antibacterial properties (Hussien *et al.*, 2011 and Belabbes *et al.*, 2017) [26, 9].

2.3 As Biosorbent

Industrial wastewater contains different toxic chemicals like heavy metals, dye and pesticides which cause serious health and environmental problems. The process of decontamination of wastewater contaminated with heavy metals, dyes and pesticides of agriculture and industrial wastewater is known as biosorbent**.** MAP waste helps in the binding of metal ions and colours in the presence of lingo-cellulosic compounds with carboxyl, hydroxyl, sulphate, phosphate, and amino groups. As a result, residual biomass from MAPs can be used as a biosorbent to remove harmful substances from water, such as metals and dyes. In one experiment, Riaz *et al*., (2013) [44], recorded that lead (Pb) uptake by immobilized *Mentha spicata* distillation waste biomass (act as bio-sorbent at 0.05 mg per litre) was greatest at pH 5, and concluded that waste biomass from distillation could be used as a biomaterial to remove Pb ions from aqueous solutions. Because of its outstanding biosorption capacity, Hanif *et al.* (2009) assert that immobilized *Mentha arvensis* distillation waste (IMADW) biomass is a useful biomaterial for removing Cu and Zn ions from aqueous solutions. *Limonia acidissima* and *Garcinia cambogia* fruit shell or peel are used as biosorbents to remove colour and metal (Torane *et al.*, 2010; Kamala *et al*., 2005) [60, 34].

2.4 As substrate for biofuel and biogas production

Biofuel is a term that refers to the process of converting biomass into liquid, solid, or gas fuel. The demand for bio-based fuels (ethanol) has been quickly expanding due to its dual usage as a fuel and for key chemical synthesis. According to Himmel *et al.* 2007 [25], steam distillation can overcome biomass recalcitrance in essential oil-bearing aromatic crops. As per Zheljazkov *et al.*, (2018) [65] in comparison to biomass that has not been pre-treated with hot steam, steam treated biomass can readily be converted to ethanol. Lemongrass and palmarosa produced 198 ml and 170 ml ethanol per gram biomass (Joyce *et al.*, 2015) [32]. According to Deshmukh *et al.*, (2015) [21], lemongrass bio-oil has a high heat value, low PAHs, and nitrogenous chemicals, making it a viable choice for fuel. Cellulose obtained from aromatic waste has converted to hydroxymethylfurfural, which may be utilized to make a variety of furan monomers like 2,5-dimethyl furan (DMF) that intake higher anti-knock properties than gasoline and is also suitable factor for liquid transportation fuel (Rout *et al*.,2015) [45]. These findings encourage the use of MAP waste for biofuel production as well as the commercialization of co-products.

Biogas, on the other hand is a sustainable, high-quality fuel that can be used instead of fossil fuels for different energy services such as heating, mutual heat and power, or as a car fuel (Machunga 2012) [36]. The most efficient approach to make biogas is to hydrolyze complex lignocelluloses into smaller molecules, which are subsequently anaerobically digested by methanotrophic bacteria to produce methane gas. Temperature assimilation and duration, total volatile solids (TVS), type and concentrations of substrates are all critical factors in determining the quality and quantity of biogas generation (Xianwen *et al.*, 2000) [62]. Alfa *et al.*, (2014) [2] reported that lemongrass provided better quality biogas with the maximum cooking efficiency than poultry droppings and cow dung even though poultry dropping were showing the highest biogas production. However, the high-water content of waste residues from essential oil-bearing aromatics is a concern because it still contains some essential oil (Slavov *et al.* 2017a, 2017b) [57, 58], which could be destructive to microorganisms such as methanotrophic bacteria during the anaerobic digestion process (Zema *et al.*, 2018) [64]. Microwave treatment, alkaline treatment, and pelletization are some of the pre-treatment processes for MAP residues that are used to address some of these difficulties. (Atay *et al.*, 2016; Cheng and Liu, 2009) [4, 17].

2.5 As an enzyme synthesis
The decomposition of lignocarbohydrate in plant materials for biofuel, animal feed, chemical feedstocks, silage, and feed additives by using enzymes such as cellulases, ligninases, and pectinases (Amalfitano *et al.*, 2018; Caruso *et al.*, 2016) [3, 14]. With a 20–30 percent annual growth rate, India's overall market for industrial enzymes is estimated to approach US$ 361 million by 2020 (India industrial enzyme market: forecast and opportunities, 2020). Agricultural residues can be used as a substrate to minimize enzyme manufacturing costs, which will help with the waste disposal problem in the herbal sector and prevent pollution. Studies revealed that delignified bioprocessing of residual biomass from MAPs like Java citronella (*Cymbopogon winterianus*) and *Artemisia annua* (also known as marc of Artemisia) resulted in the synthesis of cellulase enzymes while also lowering the cost of enzyme production (Chandra *et al.* (2009) [16].

2.6 Antimicrobial activity
Antibiotic-resistant strains of clinically significant infections are becoming more prevalent due to which different plant extracts have been tested for antibacterial activity with the goal of finding antibiotic alternatives that are both safe and effective (Britto *et al.*, 2011) [19]. Since essential oil of medicinal and aromatic plants possesses good potential against microorganisms due to which the plants are used as novel antimicrobial substances. The major biologically active ingredient in aromatic plants is polyphenolic substance, which has been discovered to have antioxidant, antimicrobial, antiprotozoal, antiparasitic, anti-inflammatory, and antifungal activities (Christaki *et al.*, 2012) [18]. According to Bokaeian and Saeidi (2015) [11], *Staphylococcus aureus* was resistant to six antibiotics, with the highest minimum inhibitory concentrations (MIC) of extract being 250 ppm against 12 strains and the lowest being 63 ppm against two strains. They also suggested that an ethanol extract of *W. somnifera* leaf may be utilized to treat a variety of infectious disorders caused by the pathogen.

2.7 As an Animal feed
Medicinal and aromatic plant waste contains fiber such as cellulose, hemicellulose, lignin, and silica as well as crude protein quality, making it an ideal by-product for animal feed. After the soluble have been extracted from ginseng with solvents such as water or alcohol (70-75%), a residue is produced, known as ginseng meal. Ginseng meal boosted the milk supply and milk quality of dairy calves, as well as the growth rate of chicks, according to studies (Kim *et al.*, 1994) [35]. According to the record obtained from dairy portal knowledge 2019, it has been found that in India dehusked isabgol seed is used as cattle feed due to the richness of starch, protein and fatty acids in seed coats. After extracting the essential oils from lemongrass leaves, Ventura *et al.* (2012) [61] discovered that it could be more effective to ensiled with whey and sugarcane molasses as additives to accelerate lactic acid growth at low pH and produce the finest quality silage.

2.8 As a soil amendment
A soil amendment is anything that improves the health of the soil biologically or organically. It can be done through mulch, biochar and compost produce from MAPs waste biomass as it contains a significant quantity of organic matter. It could be a low-cost, easily accessible input for organic and integrated farming (Sarkar *et al.*, 2017) [51].

2.8.1 Organic mulching
It's done to keep the soil moist, warm, and increase the soil structure, microbial community and nutrient availability. Using MAPs biomass waste as mulch has been found to reduce ammonia volatilization and increase nitrogen use efficiency and check the weed growth (Patra *et al*., 1993) [41]. When compared to non-mulched soil, using the distilled waste of citronella and Japanese mint as mulch could increase the crop production by retaining soil moisture content at 2–4% and increased nitrogen fertilizer use efficiency by 10% (Ram and Kumar, 1997; Patra *et al*., 1993) [43, 41]. In comparison to non-mulched soil, Singh (2013) [55, 56] reported that using organic mulch (lemongrass wasted material @ 7.5 t ha-1) increased the herbage and oil yield of rosemary with 16 and 24 percent, respectively. It has been discovered that increasing the usage of fertilizer N through organic mulch can significantly reduce pollution and cultivation costs. Mulching with distillation biomass of Java citronella @ 3-7.5 t ha-1, on the other hand, can avoid aromatic grass output loss by 40% by minimizing weed infestation (Singh *et al*., 1991, 2001) [52, 53]

2.8.2 Biochar
It's a pyrogenic carbon-rich substance that can be utilized as an agricultural and environmental soil supplement. The MAPs remaining biomass is either mulched or burned, creating greenhouse gases (GHG) and polluting the air. So, to tackle this issue, an effective valorization process of residual biomass is required to reduce environmental risk while also increasing farmer revenue. It has been reported that the using biochar as a soil amendment has increased agricultural yield as well as improved soil fertility (Jha *et al.*, 2010) [31]. Biochar made from Japanese mint (*Mentha arvensis*), had a cation exchange capacity, calcium carbonate equivalence, and accessible plant nutrients (Nigam *et al.*, 2018) [37], and was an effective low-cost solution for soil fertility augmentation. By lowering nutrient (NH_4-N, NO_3-N, and PO_4^{-3}) loss, biochar produced from Java citronella (*Cymbopogon winterianus* Jowitt) was shown to be more effective than FYM and vermicompost in improving nutrient utilisation and plant production (Yadav *et al.*, 2019) [63]. Biochar has been discovered to be beneficial not only for fertilizer distribution and efficiency, but also for soil pollution and contamination (Jain *et al.*, 2016; Jain *et al.*, 2017; Nigam *et al.*, 2019) [28, 29, 38]. It has also been reported that biochar made from Japanese mint has efficiently reduced lead (Pb) availability in soil by transferring from the available to the unavailable pool

(applied @4% to the soil) (Nigam *et al*., 2019) [38].

2.8.3 As a Composts

The continuous increase in the price and demand of chemical fertilizers in global agriculture and the huge carbon production stressed the need to formulate efficient nutrient management strategies based on cost-effective and environment-friendly nutrient sources. Recycling waste biomass, crop residues, animal manures as well as naturally occurring lowgrade minerals has been regarded as an avenue to reduce the need for costly synthetic fertilizers (Basak, 2017) [5]. In India after the extraction of essential oil through the distillation of aromatic plants contributes 3 Mt of solid biomass every year (Saha and Basak, 2019) [46]. Agricultural soils have also been found to benefit from compost and biochar in terms of physical, chemical, and biological qualities. (Sanchez-Monedero, 2018; Saha *et al*., 2019; Basak *et al*., 2020) [46, 8]. Phosphorus-enriched compost made from isabgol straw and rock phosphate is more successful than commercial P fertilizer at increasing Senna (*Cassia angustifolia*) herb yield and quality, according to studies (Basak and Gajbhiye, 2018) [7]. According to Basak (2018) [7], potassium enriched compost (3.11 percent K) produced from palmarosa distillation waste biomass shows more effective K source in extensively worn soil than chemical fertilizer.

Some research has been done to convert the remaining biomass of medicinal and aromatic plants into compost using vermicomposting in order to meet crop nutritional requirements. Vermicomposting is a well-known green technology for value addition for the biomass residues which is way more convenient for composting or recycling of the distillation of biomass. Vermicompost prepared from biomass of mint (*Mentha arvensis*), citronella (*Cymbopogon winterianus*), and patchouli (*Pogostemon cablin*) reduced chemical fertilizer use although increase soil organic carbon and accessible nutrients (Kalra *et al*., 2013, Singh *et al.*, 2013, Boruah *et al.*, 2019) [33, 55, 56, 13]. According to certain studies, the indigenous earth worm (*E. eugeniae*) is more successful than conventional compost at converting citronella distillation material into vermicompost with higher plant nutrient content (Deka *et al* 2011; Boruah *et al*., 2019) [20, 13]. Pandey and Kalra (2010) [39] stated that aqueous vermicompost made from mint, isabgol, and lemongrass was particularly efficient against the root-knot worm (*Meloidogyne incognita*) in tomato plants, when compared to the control, it also reduced the amount of hatching eggs. The presence of nematode inhibitory compounds (nematicidal principles) in the residual biomass of MAPs could explain the subsequent worm infestation reduction.

3. Conclusion

The use of MAP residual biomass as a waste disposal approach is a low-cost waste disposal technique that also has social and environmental advantages. The possibility of environmental concerns is reduced by converting residual biomass from MAPs into value-added products. Waste from medicinal and aromatic plants can be profitably recycled and bio converted, such as isolating phytochemicals and phenolic-antioxidants for use in dietary supplements, pharmaceuticals, cosmetics, and perfumes. Additional economic benefits will be generated for MAPs stakeholders by using residual biomass as a raw material for animal feed, biogas, biosorbent, soil amendment, and biopesticides. In this respect, the valorization of MAPs are need to be explored for economic development of the society as well maintain the healthy environment around us.

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