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Sustainable strategies for floral waste – A review on valuable products from floral waste and their usage

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Abstract: Flowers are the beauty of the environment. They are used only once and not disposed properly. Waste generation from the used-out flowers is of major pressing concern because it contributes to the environmental pollution. This leads to water contamination by dumping into the water bodies, and also raises land filling constraints. Thus, floral waste management needs an eye to address. This review paper discusses about the various methods to upscale the floral waste to valuable products and recycling. Some of the value-added products from floral waste include vermicomposting, natural dyes, essential oils, and food products etc. Floral waste can also be converted into energy i.e., bio-fuels. The extracts from the floral waste have a significant role in medicine and pharmaceutics as well. All these methods can reduce the pollution caused and also improves the livelihood of people by providing employment.

Keywords: *Pollution; Floral waste management; Value added Products; Employment; Adsorption*

1. Introduction

A major concern in the world is disposal of waste generated. concern for the temple management is the safe disposal of floral waste (Waghmode *et al.* 2018a) .substantial flower waste is produced from hotels, temples, churches, dargahs, and various cultural ceremonies. Religion, in India is a path of life and flowers are integral part in the culture (K. D. Yadav *et al.* 2022). After the purpose served, flowers are discarded into water bodies and leads to environmental hazards (Akanksha 2022).

Conventional methods of floral waste disposal, due to aerobic decomposition release greenhouse gases into air causing pollution (Ahmed 2021). Kitchen waste degrades at a very faster rate than floral waste (K. D. Yadav *et al.* 2022).West Bengal ranks fourth in flower promotion, following Andhra Pradesh, Karnataka, and Tamil Nadu (Adhikary 2020). Most Indian holy cities, including Shirdi, Haridwar, Gaya, Kedarnath, Patna, Tirupati, etc., doesn't have floral waste disposal policies in place (Choudhury & Deka 2023). The floral waste thrown gives a filthy look and distorts the Ghats along the rivers. every year, nearly 80,00,000 tons of flower wastes is released into the Indian rivers (Gaikwad *et al.* 2021).

Commercializing floral waste aligns with broader sustainability goals by transforming waste into valuable products, offering a holistic alternative to linear resource consumption (Choudhury & Deka

2023). Modern approaches convert the floral wastes into value- added products viz., compost; dyes; food products; incense sticks; biofuels; organic acids: bioethanol; pigments; bio surfactants production; sugar syrup; handmade paper production; etc (Ahmed 2021; Salahat *et al.*, 2023). The "Green Temples" concept aims educating priests and devotees and encouraging the use of biodegradable materials or digital offerings, which can transform spiritual sites into eco-friendly spaces (Dwivedi 2024).

Flower waste can be recycled, reused and converted to value added goods due to their high sugar content, delightful aroma and vibrant colors. It is estimated that around 500 tons of silver nano-particles are produced annually, making it one of the most commercially available nano-materials and applicable in food, medicine, chemistry, biochemistry and other fields. Silver has inhibitory bactericidal effects, as well as anti-inflammatory, antifungal and anti-angiogenic effects (Reddy *et al.* 2023). Various applications of value-added products from floral waste are depicted in Figure 1. Flower waste may produce bioenergy or heat energy (burning). And potentially used as a feed for energy production. Because of religious sentiments, management and handling of flower waste is difficult when compared to the kitchen and other municipal waste (Kumar *et al.* 2020).

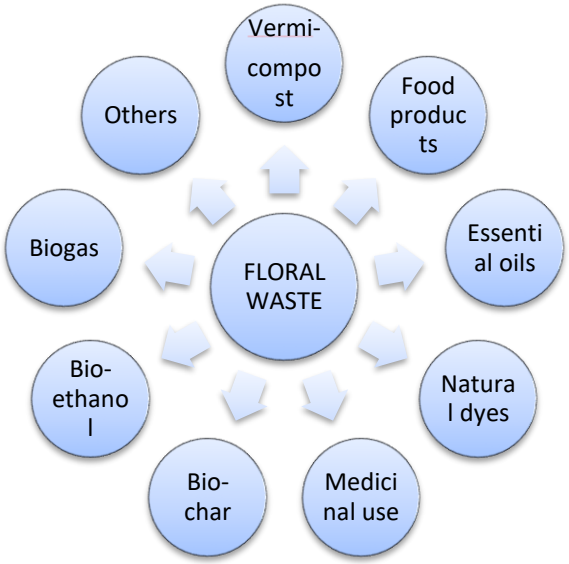

Figure 1: Various applications of floral waste (Akanksha 2022).

Roughly 8 MT of discarded flowers are dumped into water bodies in India each year. This waste choke and pollute rivers with pesticides and chemical fertilizers used to grow the flowers (Chawla 2023). Floral waste utilization is beneficial to the society and the “green temple concept” is helpful in Government policy formulation in promoting sustainable development approach towards temples (Mahindrakar 2018).

2. Value added products from floral waste

2.1. Vermicomposting

Biological conversion process of organic materials with joint action of earthworm species and microbes is vermicomposting (K & N 2021). The process involved drying and pulverizing the flowers. Various combinations of flower powder and coal powder were mixed into the soil. Subsequently, 100 to 200 worms were introduced, and the conditions-maintained moisture (40-50%), pH (6.3 to 7.5) and temperature (20-30°C). That had a positive impact on germination, plant growth and crop yield (Reddy *et al.* 2023).

The vermicompost obtained was rich in C (28%), N (1.58%), P (0.33%) and K (0.28%) and converted floral waste to useful organic fertilizer (Waghmode *et al.* 2018a). Plant hormones like auxins and gibberellins and enzymes which trigger plant growth and deject plant pathogens are also present (Adhikary 2020). Bad odors, flies, and water not draining/too wet, worms wandering/leaving bins etc. are troubleshoots (Carmen 2015). This technique is cheap, easy and pollution free. Compost is being applied to agriculture land to increase fertility (Patidar & Francis 2020). Flower waste vermicompost was rich in Na, K and P that are essential for the plant growth (Sharma & D. Yadav 2017).

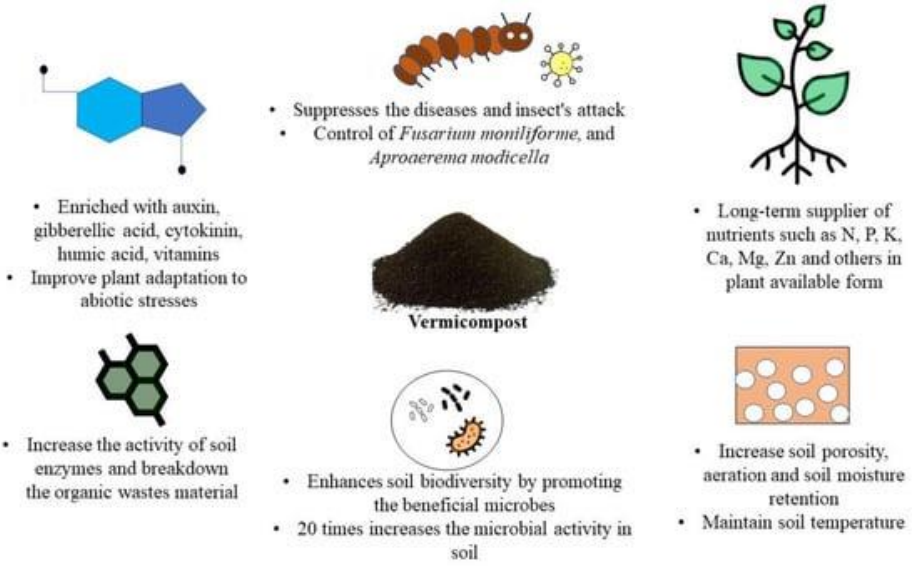

Figure 2: Advantages of vermicompost (Rehman *et al.* 2023)

C: N ratio	13
electrical conductivity	3.39 mS/cm
pH	7.10
phosphorous	5.31 g/kg
potassium	14.45 g/kg
total organic carbon	34.01%

Table 1: Optimum proportions of vermicompost (Sharma *et al.* 2021).

2.2 Food products

The use of flowers as food is noted in various cultures globally, both as a component of traditional cuisine and in alternative medicine (Takahashi *et al.* 2020). Marigold flowers are a natural source of xanthophylls, and their extract is commonly used as an additive in various food industries (Waghmode *et al.* 2018a). Food products Mahua flower extract finds application in the food industry for crafting a variety of products such as jams, jellies, biscuits (Reddy *et al.* 2023).

Rosmarinus officinalis Linn. or Salvia rosmarinus Spenn., commonly known as rosemary, stands as a botanical treasure with a rich history deeply intertwined with diverse cultural, medicinal, and culinary traditions. Among the plethora of active compounds within rosemary, rosmarinic acid, phenolic diterpenes like carnosic acid and carnosol, flavonoids, and the essential oil have emerged as key players in contributing to its diverse biological activities (Meziane *et al.* 2025; Mena *et al.*, 2016).

Carotenoid composition of marigold (*Tagetes erecta*) flower extract is nutritional supplement (Anvitha *et al.* 2015). The marigold petals contain a high level of lutein and used as coloring agents in

the food and feed industries, and also as antioxidants (Chauhan *et al.* 2022). Anthocyanins used as colorants were extracted from red rose petals (Marathe *et al.* 2021). Maize flower contains Ca, Na, Mg, K, Fe, Cu, and Zn in varied concentrations (Bujang *et al.* 2021).

Floral pollen in the formulation of functional food and feed products (Kostić *et al.* 2020). **Gulkand** is an excellent rejuvenator and a powerful antioxidant , which improves appetite, digestion and has a cooling effect on the body (Trivedi 2021). Flower sugar syrup have more values than cane sugar syrup in sugar analysis and use it in food products (A S & CHINNAMMA 2021). Marigold flowers are used in food industry for their nutritive qualities as well as coloring of culinary products (Hamad *et al.* 2017).

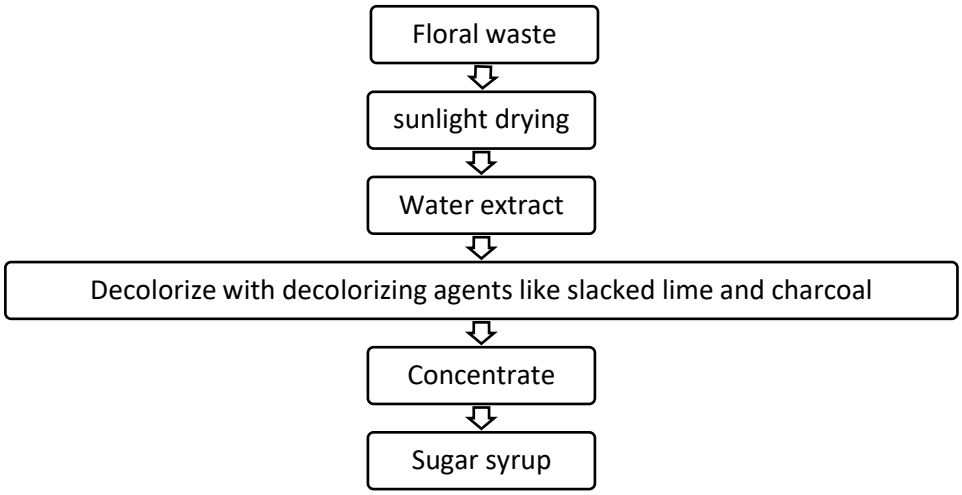

Figure 3: Process of making sugar syrup from floral waste (A S & CHINNAMMA 2021)

2.3. Essential oils

Floral essential oils are primarily extracted from the flowering parts of plants, capturing the natural sweet and fragrant aromas of the flowers (Swati *et al.* 2024). Essential oils have many traditional uses, such as in the foods and herbal remedies, with less "side-effects" on human health (Voon *et al.* 2012). **Figure 4,** gives the benefits of essential oils. The essential oil was successfully extracted from dry petals of flowers using solvent extraction or maceration (Priyanka D. Dhandge & Swati P. Deshmukh 2024). VOC's emitted from the rose flowers help attract various pollinators (Hosseini *et al.* 2020). *H. sabdariffa* essential oil contained 17 compounds representing 99.8% of the total oil content (Lawal *et al.* 2014).

Figure 4: Benefits of essential oils (Paul 2022).

Flower essential oils (secondary metabolites) are liquids composed of volatile and aromatic compounds extracted from edible flowers. They are widely used in the cosmetics and medicine industries due to their beneficial properties (Chen *et al.* 2021; Cherriet *et al.* 2023; Taibi *et al.* 2024). Floral essential oils' therapeutic and medical characteristics improve the health of hair, skin, and other body parts in a variety of ways (Robinson 2024). Chamomile essential oil is used to treat skin disorders such as eczema and to relieve muscle cramps (Adhikary 2020), used also as corrosion inhibitor for steel in acid media (Hmamou *et al.* 2012). Rose essential oils and extracts possess therapeutic properties, functioning as respiratory antiseptics, antioxidants, anti-inflammatories, and mucolytics. They can serve as both symptomatic preventatives and treatments, helping to alleviate significant discomfort during severe illnesses (Mileva *et al.* 2021).

Calendula oil, made by infusing dried calendula flowers in olive oil, serves as excellent massage oil, and Passionflower is known for its ability to alleviate anxiety, stress, and insomnia (Reddy *et al.* 2023).

2.4. Natural dyes

Natural dyes are eco-friendly as they are renewable and biodegradable (Ragab *et al.* 2022). Chamomile flower can generate colors with greenish or yellowish shade (Menegazzo *et al.* 2020). Natural dyes have non allergic effects; non toxic in nature and results in less environmental pollution (Dhanalakshmi & Sathya 2022). Natural dyes extracted from hibiscus and marigold flowers show a very good potential to dye cotton and cotton/silk blended fabrics (I. Yadav *et al.* 2015). Hexane, methanol, and ethanol solvents are used to dissolve dried and ground flower waste in the extraction and dyes can be used as a colouring agent on clothing (Atal 2022). **Figure 5** show the process of natural dye extraction and **Figure 6** shows the advancements.

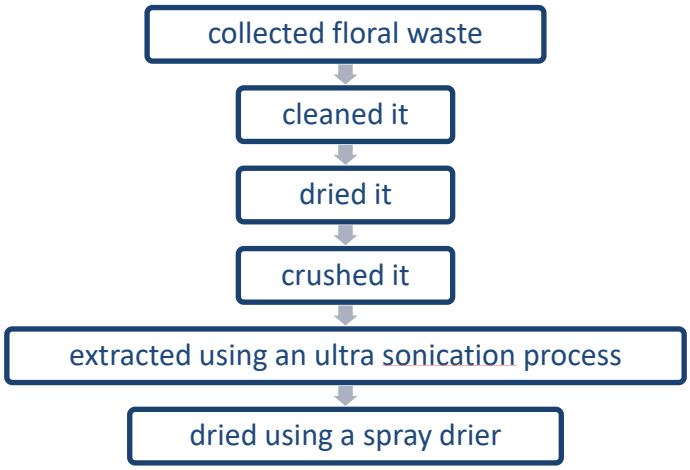

Figure 5: Flow chart of natural dye extraction (Reddy *et al.* 2023).

Flowers display their colors due to the presence of carotenoids, betalains, and anthocyanins (Ahmed 2021). Natural dyes from rose residue have applications in dye-sensitized solar cells (Bennurmath *et al.* 2021). Industrials are turning to natural substances because the authorized organic synthetic dyes tends to decrease under pressure from regulations and consumers (Lachguer *et al.* 2023). The natural dye is rich in phenols and flavonoids and revealed a high scavenging effect, an excellent reducing power, and a high antioxidant activity (Lachguer *et al.* 2023). The Pashmina shawl is applied with saffron flower extract. The potential use of Hibiscus as a natural dye in textile coloration has been reported (Waghmode *et al.* 2018b).

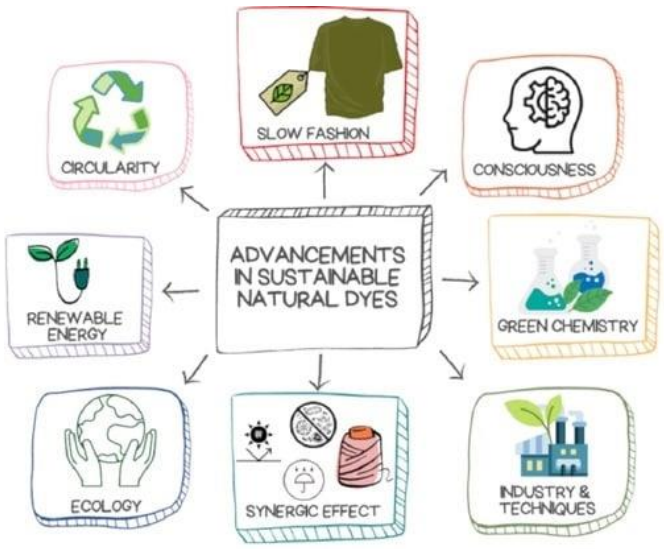

Figure 6: Natural dye advancements (Pizzicato et al., 2023).

2.5. Medicinal use

Since ancient times, flowers have their medicinal imprint in the original course textbooks of Ayurveda-Charaka Samhita, Ashtanga Hridaya, Sushruta Samhita, , and Bhavaprakash Samhita (S. Kumar *et al.* 2022). Figure 7, gives the medicinal use of some of the flowers. Phytochemicals which contribute to the health benefits, are present in edible flowers (Lu *et al.* 2016). Safflower is beneficial for various ailments related to the neurotropic, cardiotropic, hemopoietic, and diaphoretic systems (Delshad *et al.* 2018). The flowers of Jasmine suppress excess lactation after childbirth. Neem flowers showed antibacterial activity against *Staphylococcus aureus*. The flowers of Butea possess anticonvulsant activity (Rizvi & Ali 2016). *C. officinalis* flowers are traditionally used to treat gastrointestinal ulcers, and various saponins have demonstrated strong gastroprotective effects (Yoshikawa *et al.* 2001).

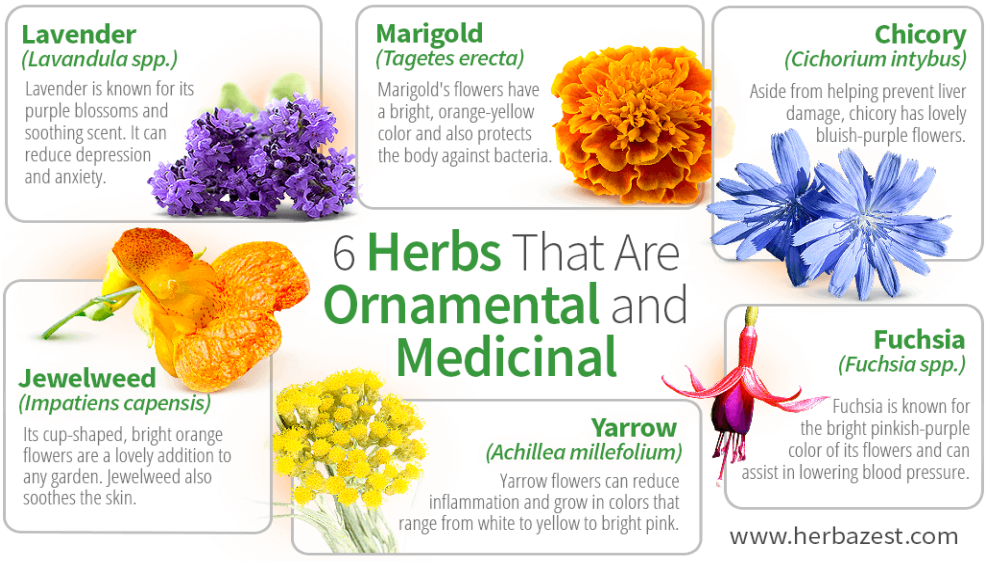

Figure 7 : Medicinal flowers (D 2018).

Calendula has highly effective anti-bacterial, anti-helminthic, anti-fungal, anti-molluscal and anti-inflammatory properties (John & Jan 2017). Extracts of dried flowers from *Calendula officinalis* are examined for its inhibitory effects on HIV-1 (Hamad *et al.* 2017). Lotus is also a rich source of

phytochemicals, which are solely responsible for their medicinal activity (Ranchana *et al.* 2023). The flower of *Lavandula angustifolia* is used in perfumes and in aromatherapy because its fragrance claimed calming effect (Yeung *et al.* 2018). Flowers have significance to maintain health, treat diseases, to enhance beauty from long times, manufacture cosmetic products which are crucial and also creates a fresh, elegant and warm atmosphere that helps in relaxing mind, in Unani System of Medicine (Negi & Siddiqui 2020).

2.6. Biochar

Highly carbonaceous material with high surface area and several micro- and macro-nutrients along with functional groups is biochar (P. Singh *et al.* 2018a). Biochar improves soil, increases nutrient retention, and mitigate global climate change (P. Singh *et al.* 2018a). Biochar can be directly implemented to the dye elimination process from the industrial effluents including various other wastewater remediation's (Titikshya *et al.* 2023).

Biochar is obtained from woody component of flower via slow pyrolysis. Biochar is used in purifying wastewater (Choudhury & Deka 2023). The dry flower has poor efficiency in water decontamination, therefore it is converted to charcoal by controlled burning (Agarwal *et al.* 2021). Figure 8, demonstrates the biochar production from floral waste. Biochar is highly pH sensitive. The maintenance cost of system can be relatively high. For prolonged use, continuous regeneration or desorption may be needed (Osman *et al.* 2023). Identifying the specific and unique application for flower-based biochar among other feedstock is the future scope (Panditha *et al.* 2021).

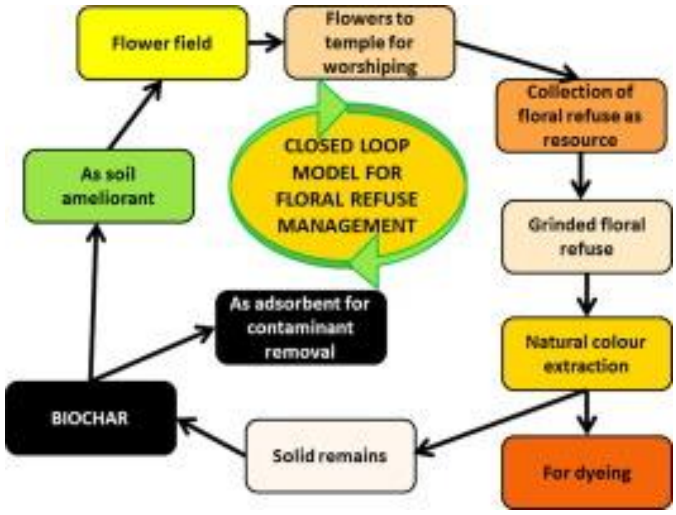

Figure 8: Bio-char from floral waste (P. Singh *et al.* 2018b)

2.7. Bioethanol

Bioethanol is an alternative energy source and can be used as a gasoline or as mixture to diminish the use of gasoline. It is expected to replace fuel oil in vehicles and can decrease air pollution (Nugrahini *et al.* 2022). Bioethanol derived from flower waste can be blended with other fuels to enhance its energy efficiency, offering an eco-friendly solution (V. Kumar *et al.* 2020).

Marigold flower can be a potential source of ethanol production because of fermentable sugars (Doda & Sahu 2022). Utilized jasmine flower is suitable substrate with high portion of organic carbohydrate and other organic acids for bioethanol production (Khammee *et al.* 2021). Withered flowers could serve as a better alternative for bioethanol production compared to using food crops (Y. Gethara Gowri Rekha 2018).

2.8. Biogas

Biogas can be produced from flower waste through anaerobic digestion technology (Choudhury & Deka 2023). Using floral waste as substrate provides an energy-efficient solution (Kulkarni & Ghanegaonkar 2019b). Figure 9, depicts the flowchart of biofuel making from floral waste.

The use of floral waste gives high yield of bio gas. Kumar and Swapanvahini have generated biogas from flower waste containing rose petals with reduced concentration of Total Solids, Volatile Solids, Chlorides and BOD (Rani *et al.* 2020). Floral waste anaerobic digestion is a viable source of biogas energy and also reduce environmental pollutions (Kulkarni & Ghanegaonkar 2019a). This concept can also be seen as waste to energy to enhance environmental sustainability (Lakshmi & Vijayalakshmi 2017). Biogas can be used directly for cooking as well as for power generation (Kabeyi & Olanrewaju 2022).

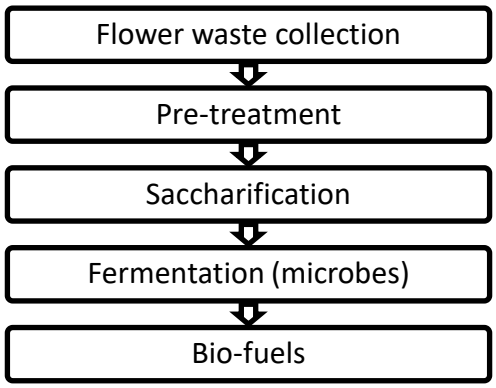

Figure 9 : Process of bio-fuel making (Adhikary 2020)

3. OTHER PRODUCTS FROM FLORAL WASTE

Decoctions of *Azadirachta indica* (Meliaceae) flowers, juices from *Calendula officinalis* (Asteraceae), flower pastes of *Momordica charantia* (Cucurbitaceae) mixed with olive oil, *Phyllanthus niruri* (Euphorbiaceae) flower pastes, *Piper nigrum* (Piperaceae) flower pastes with ghee, juices from *Pluchea indica* (Asteraceae), and pastes from *Solanum torvum* (Solanaceae) are used as precautions against snakebites. Additionally, floral waste can be repurposed as a snake repellent, providing both economic and environmental benefits. (Punetha & Vuppu 2023). Investigators wanted to exploit the use of flowers in dyeing and printing of cotton fabric (Meena Batham & Sonali Mandhary 2023). Flower pounding is an inexpensive, easily taught, and eco-friendly alternative to printmaking with synthetic dyes (Ratnayaka & Haar 2022).

Flower waste has a great potential as a substrate for the production of bio-surfactant, having a high demand in every industrial sector of food, pharmaceutical, agriculture, cosmetics, textile, detergent, paper and petroleum industries (Seikh & Owary 2023).

There is demand of lutein as dried petals are added to the poultry feed intensifies the yellow colour of egg yolks and broiler skin. Various flower ornaments have been used by the people from time immemorial like garland, veni/gajra, wreath etc (Pandey *et al.* 2020). Metal nanoparticles are synthesized from utilized flowers and showed many biological activities. *Mimosa pudica* flower extract synthesized gold nanoparticles have photo catalytic activity; Copper oxide nanoparticles synthesized showed antioxidant activity, from *Magnolia champaca* floral extract (Donga & Chanda 2020).

The dried marigold petals were used to make incense stick. The prepared product can be commercialized to promote daily wages earning to needy people (Saoji *et al.* 2021). Flower incense sticks do not contain the smoke such as particulate matter and volatile compounds which cause

pollution (Kalyankar 2024). Hibiscus rosa sinensis extract is an additive for homemade soaps (Indirani *et al.* 2022). Ylang flower extract is used as a fragrant in soap and with active compounds can trap free radicals. The combination of ylang flower extract, oil (Olive, Palm, and Coconut) resulted in an antibacterial solid soap that has gentle properties and a natural scent (Aktawan *et al.* 2023).

Production of paper from floral waste would reduce deforestation. Paper obtained from floral waste is eco-friendly, cost-effective and biodegradable (Mohan *et al.* 2018). The paper primarily was made of marigold flowers (*Calendula officinalis*) obtained from a flower market. A paper variant also included the use of tuberoses (*Polianthes tuberosa*) along with the marigold flowers (Sheth *et al.* 2021).

Dried flowers are utilized as biosorbents for the removal of heavy metals from contaminated groundwater. When flower waste biosorbents are added, biological reactions take place, helping to regulate the concentration of contaminants (Dey *et al.* 2023). Floral extract phytochemicals contribute to the formation of green ZnO nanoparticles, that are promising adsorbents in organic pollutants removal like dyes and 2,4-dinitrophenol (Cam Nguyen *et al.* 2024). Potpourri is a significant part of the dried flower industry. It serves as a natural air or room freshener and can be displayed in the living room (Safeena & Thangam 2023). Engaging in crafting within floriculture such as making dry flowers, creating floral decor, assembling bouquets, and designing dry flower frames and articles is regarded as an excellent opportunity for livelihood and empowering women (D. A. Singh 2017).

Conclusion

Floral waste can be converted into rich compounds instead of dumping and polluting nature. From all the above methods or products derived from the floral waste, we can reuse and recycle the temple floral waste into useful things. The product can be utilized in agriculture sector as manure and fertilizer, in dyeing industry as natural colourants, in water treatment as biosorbent, for handmade paper making, and natural repellent. This not only saves the environment but also provides employment and currency for the people involved.

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