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AGRO-WASTE AS A SUSTAINABLE SOURCE OF BIOACTIVE COMPOUNDS: A REVIEW OF ITS MEDICINAL PROPERTIES AND THERAPEUTIC APPLICATIONS

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ABSTRACT

Agrowaste, also referred to as agricultural or agro-industrial waste, is made up of non-edible residues produced during crop cultivation, harvesting, and food processing, such as fruit peels, vegetable peels, seeds, husks, pomace, stalks, leaves, and bran. Previously considered waste, these by-products are now recognized as significant sources of bioactive phytochemicals, such as dietary fiber, polyphenols, flavonoids, tannins, carotenoids, alkaloids, terpenoids, and essential oils. These compounds exhibit a wide range of pharmacological activities, including anti-inflammatory, antimicrobial, antidiabetic, anticancer, cardioprotective, hepatoprotective, neuroprotective, and wound-healing qualities. Recent advances in green extraction techniques and nanotechnology have made it easier to recover these bioactive components for use in medicines, nutraceuticals, cosmetics, and functional foods. In addition to promoting the circular bioeconomy and lowering environmental pollution, the valorization of agrowaste offers affordable and sustainable sources of medicinal agents. This review highlights the potential contribution of agrowaste to sustainable healthcare and drug development by summarizing the main categories of agrowaste, their phytochemical composition, disease-specific medicinal applications, mechanisms of action, and future prospects for pharmaceutical utilization.

KEYWORDS: Peels from bananas, mangos, onions, pomegranates, agro-industrial waste, agrowaste, bioactive compounds, polyphenols, antioxidants, anticancer, antidiabetic and nutraceuticals.

INTRODUCTION

Fruit and vegetable peels, seeds, pomace, stalks, husks, shells, and leaves are among the massive amounts of solid residues produced annually by the agriculture and food processing industries. [(1)] Even though these materials contain significant amounts of biologically active compounds, a large portion of them are discarded. Economic losses, greenhouse gas emissions, and environmental contamination are all consequences of improper agricultural waste disposal. [(2)] As a result, research on turning agrowaste into useful pharmaceutical and medical products has grown in importance within the context of sustainable development and the circular bioeconomy. [(3)]

Numerous agrowastes have high concentrations of phenolic compounds, flavonoids, carotenoids, tannins, dietary fiber, pectin, vitamins, essential oils, and other secondary metabolites, according to recent scientific research.[(4)] Strong antioxidant, antimicrobial, anti-inflammatory, antidiabetic, anticancer, antiviral, cardioprotective, hepatoprotective, neuroprotective, and wound-healing properties are demonstrated by these phytochemicals. [(5)] The recovery of these compounds using eco-friendly extraction methods has created new possibilities for their use in biomedical formulations, functional foods, pharmaceuticals, nutraceuticals, and cosmetics.[(6)]

Banana peel is a fruit-derived agrowaste that has potent antimicrobial and antioxidant properties and is high in dopamine, catechins, and gallocatechin. Mangiferin, quercetin, gallic acid, and carotenoids found in mango peels have anti-inflammatory, anticancer, and antidiabetic qualities.[(11,14)] Punicalagin and ellagic acid, which have antimicrobial, gastroprotective, antioxidant, and anticancer properties, are abundant in pomegranate peel.[(12)] Quercetin and flavonoids, which are abundant in onion peel, have anti-inflammatory, antihypertensive, cardioprotective, and anticancer properties.[(13)] Hesperidin, naringin, and essential oils, which are abundant in orange peel, also have antimicrobial, antioxidant, and metabolic health benefits.[(10)]

Research on the therapeutic uses of phytochemicals derived from agrowaste has accelerated due to growing interest in disease-oriented natural therapies.[(7)] In numerous experimental studies, these bioactive components have demonstrated promising therapeutic effects against chronic diseases like diabetes mellitus, cardiovascular disorders, cancer, obesity, microbial

infections, inflammatory diseases, and neurodegenerative disorders.[8] In addition to encouraging environmental sustainability, their use offers cheap, renewable raw materials for upcoming drug development.[9]

CLASSIFICATION OF AGRO WASTE

1. Agrowastes derived from fruits

When fruits are harvested, processed, and consumed, fruit-based agrowastes are produced. Depending on the species, they make up between 25 and 60 percent of the total fruit mass and are primarily composed of peels, seeds, pomace, rinds, pulp residues, and fruit stalks. Bioactive substances like polyphenols, flavonoids, tannins, carotenoids, pectin, dietary fiber, vitamins, and essential oils are abundant in these by-products. Fruit wastes have drawn a lot of interest for use in pharmaceutical, nutraceutical, cosmetic, and functional food applications due to their antioxidant, antimicrobial, anti-inflammatory, antidiabetic, and anticancer properties.[11,14,12]




2. Agrowaste Derived from Vegetables

Agrowastes derived from vegetables are created during food processing, harvesting, and cultivation. Peels, outer leaves, stems, roots, pods, seeds, and leftover vegetable tissues are examples of these wastes. Phenolic compounds, flavonoids, carotenoids, glucosinolates, sulfur-containing compounds, vitamins, and minerals are all present in considerable quantities. Vegetable residues are promising raw materials for pharmaceutical formulations and natural therapies because of their strong antioxidant, antimicrobial, anti-inflammatory, antihyperglycemic, and anticancer properties. [1,13]




3. Agrowaste Based on Cereals

Grain processing and milling produce cereal-based agrowastes. These consist of broken grains, bran, husks, straw, chaff, and germ residues. Dietary fiber, phenolic acids, γ-oryzanol, tocopherols, tocotrienols, lignans, and vital minerals are all abundant in cereal residues. These bioactive ingredients have cardioprotective, prebiotic, antidiabetic, cholesterol-lowering, and antioxidant properties. The use of cereal agrowastes in pharmaceutical excipients, biodegradable biomaterials, and nutraceuticals is growing. [1,2,6]



4. Additional Agrowastes

Many agricultural by-products come from plantation crops, the oilseed and sugar industries, the processing of spices, and forestry, in addition to fruit, vegetable, and cereal residues.

Phenolic compounds, lignin, cellulose, hemicellulose, tannins, alkaloids, and essential oils can all be found in these materials. They have shown wound-healing, tissue-regenerative, antimicrobial, anti-inflammatory, and antioxidant qualities. Many of these wastes are presently being researched for use in tissue engineering, biomedical materials, cosmetics, and drug delivery systems. [4,8]




BIOACTIVE CONSTITUENTS PRESENT IN AGRO WASTE

Major phytochemicals include:

• Polyphenols, Flavonoids, Tannins, Anthocyanins, Carotenoids, Terpenoids, Alkaloids, Saponins, Dietary fibers, Vitamins, Minerals, Essential oils, Organic acids

These constituents contribute to antioxidant, antimicrobial and anti-inflammatory ,anticancer,anti diabetic, cardioprotective and also woundhealing activities. [4,5]

DISEASE BASED MEDICINAL APPLICATIONS OF AGRO WASTES

Polyphenols, flavonoids, tannins, dietary fibers, carotenoids, vitamins, and phenolic acids are abundant in agro-wastes like fruit peels and vegetable leftovers.[4] These bioactive substances are useful in pharmaceutical and nutraceutical applications because of their antioxidant, antimicrobial, anti-inflammatory, anticancer, antidiabetic, cardioprotective, and wound-healing qualities.[5]

Agrowaste Type	Bioactive Compounds	Medicinal Properties	Disease Applications
Banana peel[11]	Catechins, Gallocatechin, Dopamine, Gallic acid, Ferulic acid, Pectin	Antioxidant, Antimicrobial, Anti-inflammatory, Wound healing	Diabetes mellitus, Infected wounds, Gastric ulcer, Oxidative stress-related disorders
Mango peel[14]	Mangiferin, Quercetin, Gallic acid, Ellagic acid, Carotenoids	Antioxidant, Anticancer, Antidiabetic, Hepatoprotective, Anti-inflammatory	Diabetes mellitus, Liver diseases, Breast cancer, Colon cancer, Chronic inflammation
Pomegranate peel[12]	Punicalagin, Ellagic acid, Gallic acid, Ellagitannins, Flavonoids	Antioxidant, Antimicrobial, Anticancer, Gastroprotective, Anti-inflammatory	Gastric ulcer, Oral infections, Colorectal cancer, Breast cancer, Cardiovascular diseases
Orange peel[8]	Hesperidin, Naringin, Limonene, Vitamin C, Polymethoxyflavones	Antioxidant, Antimicrobial, Anti-obesity, Anti-inflammatory	Obesity, Hyperlipidemia, Type 2 diabetes, Respiratory infections
Rice bran[3]	γ-Oryzanol, Tocopherols, Tocotrienols, Ferulic acid	Antioxidant, Cholesterol-lowering, Antidiabetic	Hypercholesterolemia, Type 2 diabetes, Cardiovascular diseases
Onion peel[13]	Quercetin, Kaempferol, Anthocyanins, Phenolic acids	Antioxidant, Anti-inflammatory, Antihypertensive, Anticancer	Hypertension, Cardiovascular diseases, Diabetes mellitus, Colorectal cancer
Coconut husk[3]	Tannins, Phenolic compounds, Lignin, Flavonoids	Antioxidant, Antimicrobial, Wound healing	Skin infections, Burns, Chronic wounds

CONCLUSION

A valuable and sustainable source of bioactive compounds with substantial therapeutic potential is agrowaste. Polyphenols, flavonoids, tannins, carotenoids, vitamins, and dietary fibers with a variety of biological activities can be found in fruit and vegetable by-products like banana peel, mango peel, pomegranate peel, onion peel, orange peel, and banana flower bract. Their antioxidant, anti-inflammatory, antimicrobial, antidiabetic, anticancer, cardioprotective, hepatoprotective, wound-healing, and neuroprotective qualities have all

been proven by scientific research. Numerous chronic illnesses, such as diabetes mellitus, cardiovascular disease, cancer, gastrointestinal disorders, skin conditions, and microbial infections, can be prevented and managed with the help of these bioactive components.

Utilizing agrowaste encourages the creation of value-added pharmaceutical, nutraceutical, cosmetic, and functional food products in addition to offering a cost-effective and environmentally responsible method of waste management. Before large-scale therapeutic applications can be realized, more carefully planned clinical trials, standardization of extraction techniques, safety assessments, and regulatory frameworks are needed, despite promising preclinical and experimental results. All things considered, the efficient use of agrowaste is consistent with the circular bioeconomy and sustainable development, providing promising prospects for novel drug discovery and enhanced public health.

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