Coconut Husk Ash Extract: A Review of Its Formulations and Pharmacological Actions

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Abstract

Coconut husk ash extract, derived from the combustion of *Cocos nucifera* husk, is rich in minerals and phytochemicals with diverse pharmacological activities. Traditional formulations have long utilized this extract for antimicrobial and wound-healing purposes. Recent advances in nanotechnology have enabled the development of nano-formulations that enhance solubility, bioavailability, and targeted delivery. This review synthesizes current knowledge on the composition, pharmacological actions, conventional formulations, and nano-formulations of coconut husk ash extract, highlighting its potential in modern therapeutics.

Keywords

Coconut husk, anti-bacterial, minerals, nanoformulations, silica

Introduction

The coconut tree (*Cocos nucifera L.*), often referred to as the "tree of life," is one of the most versatile plants in tropical and subtropical regions. Every part of the coconut has been utilized for food, medicine, and industrial applications. Among its by-products, the coconut husk—traditionally considered agricultural waste—has gained increasing attention for its pharmacological potential when processed into ash extract. Coconut husk ash is produced by controlled combustion of the fibrous husk, yielding a mineral-rich residue that contains potassium carbonate, calcium oxide, magnesium oxide, silica, and trace elements, along with residual phytochemicals such as phenolics, tannins, and flavonoids.[1,2,3] Ethnopharmacological practices across Asia and Africa have long employed coconut husk ash for wound healing, gastrointestinal disorders, and antimicrobial therapy. Modern research has validated these uses, attributing them to the synergistic action of minerals and phytochemicals. However, conventional formulations suffer from poor solubility and inconsistent bioavailability. Nanotechnology now offers innovative solutions, transforming husk ash extract into advanced nano-formulations that enhance therapeutic efficacy.

Historically, coconut husk ash has been used in traditional medicine across Asia and Africa. In folk remedies, powdered husk ash was applied to wounds, burns, and skin infections due to its antimicrobial and astringent properties. Decoctions of husk ash were consumed for gastrointestinal disturbances, while topical pastes were used for inflammation and pain relief. The pharmacological relevance of coconut husk ash lies in its dual composition of Minerals and phytochemicals. This review consolidates current knowledge on coconut husk

ash extract, focusing on its composition, pharmacological actions, conventional and modern formulations, and particularly nano-formulations, which represent a paradigm shift in its biomedical applications.

2. Phytochemical and Mineral Composition

Coconut husk ash extract is a complex mixture of inorganic minerals and organic phytochemicals that contribute to its therapeutic potential.

2.1 Mineral Constituents

- **Potassium carbonate (K_2CO_3):** Major alkaline component, responsible for antimicrobial and cleansing properties.
- **Calcium oxide (CaO):** Plays a role in wound healing and bone metabolism.
- **Magnesium oxide (MgO):** Involved in enzymatic regulation and anti-inflammatory activity.
- **Silica (SiO_2):** A precursor for nanostructures; enhances drug delivery applications.
- **Trace elements:** Iron, zinc, and manganese, which contribute to antioxidant enzyme activity.

Potassium carbonate contributes alkalinity, enhancing antimicrobial activity. Calcium and magnesium oxides support tissue regeneration and enzymatic regulation. Silica provides a precursor for nanostructures, enabling biomedical applications in drug delivery.[3,8]

2.2 Phytochemical Constituents

- **Phenolic compounds:** Provide strong antioxidant activity.
- **Tannins:** Exhibit antimicrobial and astringent properties.
- **Flavonoids:** Contribute to anti-inflammatory and hepatoprotective effects.
- **Lignin derivatives:** Support structural integrity and potential anticancer activity.
- **Alkaloids and saponins:** Reported in related coconut tissues, contributing to immunomodulatory effects.
- **Phytochemicals:** Phenolic compounds and flavonoids act as antioxidants, tannins provide antimicrobial and wound-healing effects, and lignin derivatives exhibit anticancer potential. The synergy between these constituents underpins the extract's broad pharmacological spectrum.

The synergy between minerals and phytochemicals enhances pharmacological actions. For example, silica nanoparticles derived from husk ash can encapsulate phenolic compounds, improving stability and bioavailability.[6]

3. Pharmacological Actions

Coconut husk ash extract demonstrates a wide range of pharmacological activities, validated through preclinical and ethnopharmacological studies.

3.1 Antioxidant Activity

Phenolic compounds and flavonoids scavenge free radicals, reducing oxidative stress. DPPH assays confirm strong radical inhibition.[1]

3.2 Antimicrobial Activity

Ethanolic extracts inhibit *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*. Mineral alkalinity enhances bactericidal action. Silver nanoparticles synthesized using husk ash extract show synergistic antimicrobial effects.[9]

3.3 Anti-inflammatory Activity

Flavonoids and tannins reduce pro-inflammatory cytokines such as TNF-α and IL-6. Preclinical models demonstrate reduced edema and inflammation.[2]

3.4 Antidiabetic Activity

Coconut-derived phytochemicals improve glucose metabolism and insulin sensitivity. Mineral cofactors such as Mg^{2+} and Zn^{2+} support enzymatic regulation of carbohydrate metabolism.[3]

3.5 Hepatoprotective Activity

Extracts protect against chemically induced liver damage. Antioxidant minerals and flavonoids reduce lipid peroxidation and restore hepatic enzymes.[1]

3.6 Anticancer Potential

Silica nanoparticles derived from husk ash induce apoptosis in cancer cells. Lignin derivatives and phenolics show cytotoxicity against tumor lines.[6]

4. Formulations of Coconut Husk Ash Extract

- Decoctions and extracts are used in ethnomedicine.
- Powdered ash is incorporated into herbal remedies.
- Topical ointments of coconut husk ash are applied for wound healing
- Capsules and tablets are standardized for mineral content.
- Hydroalcoholic extracts are used for enhanced solubility.
- Polyherbal combinations are used for synergistic effects.

5. Nano-Formulations: Enhancing Therapeutic Potential

Nanotechnology has transformed coconut husk ash extract from a traditional remedy into a modern biomedical resource. Its mineral-rich composition (silica, calcium, magnesium) and phytochemicals make it an excellent precursor for nanoparticles, nanocellulose, and nanostructured composites. Below are detailed case studies and mechanistic insights.

5.1 Silica Nanoparticles from Coconut Husk Ash

Pattanayak et al. (2022) produced amorphous silica nanoparticles from coconut shell and coir. The particles exhibited high surface area and porosity, making them suitable for drug delivery. The Silica nanoparticles act as carriers for bioactive molecules. Their porous structure allows encapsulation of phenolic compounds from husk ash. Controlled release improves bioavailability and reduces degradation in the gastrointestinal tract. These silica nanoparticles find application in anticancer drug delivery, biosensing, and hepatoprotective formulations.[10]

5.2 Nanocellulose from Coconut Husk Fiber

Poornachandhra et al. (2023) synthesized nanocellulose from coconut husk fiber as a low-cost bioresource. The nanocellulose provides a biocompatible scaffold for sustained release of phytochemicals. Hydrogen bonding between cellulose nanofibers and phenolic compounds stabilizes the formulation. Its high mechanical strength supports wound-healing dressings. They can be used in preparation of wound healing films, oral drug carriers, and tissue engineering scaffolds.[11]

5.3 Crystalline Silica Nanostructures

Studies on crystalline silica derived from husk ash demonstrated unique optical and physical properties. The crystalline silica interacts with cellular membranes, enhancing uptake of encapsulated drugs. Its optical properties allow use in photodynamic therapy and biosensors. These find importance cancer diagnostics, photothermal therapy, and antimicrobial coatings.

5.4 Green-Synthesized Metal Nanoparticles

Coconut husk ash extract has been used as a reducing agent for silver and gold nanoparticle synthesis. These nanoparticles showed strong antimicrobial activity against resistant strains. Phytochemicals (flavonoids, tannins) act as reducing and stabilizing agents. Nanoparticles disrupt bacterial cell walls and generate reactive oxygen species (ROS). Synergistic action with mineral alkalinity enhances bactericidal effects. They can be used as antimicrobial coatings, wound dressings, and food preservation.[12,13]

5.5 Nanoemulsions and Liposomal Systems

Although direct studies on husk ash nanoemulsions are limited, coconut-derived extracts have been incorporated into nanoemulsions for improved solubility. Nanoemulsions enhance solubility of hydrophobic phytochemicals. Liposomes encapsulate ash-derived compounds, protecting them from degradation. Both systems improve systemic absorption and therapeutic efficacy. They can be used as for oral delivery of antioxidants, hepatoprotective agents, and anti-inflammatory drugs.

These nano-formulations encapsulate unstable phytochemicals, enable targeted delivery, and provide synergistic antimicrobial and anticancer effects and exhibit higher advantages.

- **Encapsulation & Controlled Release:** Nanostructures protect unstable phytochemicals and release them gradually.
- **Targeted Delivery:** Silica and metal nanoparticles enable site-specific drug delivery.
- **Synergistic Antimicrobial Action:** Combination of mineral alkalinity and nanoparticle ROS generation.
- **Biocompatibility:** Nanocellulose and liposomes provide safe carriers for biomedical use.

6. Conclusion

Coconut husk ash extract demonstrates broad pharmacological potential, particularly when integrated into nano-formulations. These advanced systems enhance bioavailability, stability, and therapeutic efficacy, making the extract a promising candidate for antimicrobial, antioxidant, and anticancer applications. Bridging traditional knowledge with modern nanotechnology could establish coconut husk ash extract as a sustainable biomedical resource.

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