Diamond from Dross: A Natural Pistachio Hull Bioactive Shield for Skin Defense in Wild Environments

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Abstract
Exposure to infectious insects while walking or working in wild and forested environments poses a significant risk of vector-borne skin infections and irritation. This research focuses on the development of a natural skin-protective "shield," formulated as a topical body serum named The Defenders, designed to act as a barrier against insect-associated microbial exposure. The formulation uses pistachio hull as the primary raw material—an agro-waste by-product rich in bioactive compounds. Pistachio hull contains natural exfoliating agents, potent antioxidants, and bio-protective pigments such as lutein and zeaxanthin, which contribute to skin defense, cellular protection, and the reduction of oxidative stress. The hull extract is blended with Santalum (sandalwood) paste or diluted in water to enhance soothing, antimicrobial, and skin-cooling effects, allowing for easy topical application in a serum-based form. The synergistic interaction of these natural components is proposed to strengthen the skin's surface barrier, reduce microbial adhesion, and provide effective protection against infectious insects without the use of synthetic chemicals. This eco-friendly formulation emphasises the sustainable utilisation of plant-based waste materials and presents a promising natural alternative for personal skin defense during wilderness and outdoor exposure.

Keywords: Pistachio Hull, Bioactive Compounds, Natural Skin Shield, Insect-Borne Protection, Topical Formulation

Introduction

Pistachio green hull (PGH), derived from Pistacia vera L., is the outer fleshy covering of the nut that is removed as a major by-product during processing (Mohammadi Moghaddam, Razavi, Malekzadegan, & Shaker Ardekani, 2009). Although it is largely discarded as waste, PGH is rich in bioactive compounds such as polyphenols, fibre, and antioxidants. It also contains vitamin E, which helps enhance skin hydration and protection.

Naturally, the hull provides rigidity and protection to the kernel—the softer, edible part of the pistachio. Interestingly, as valuable as the pistachio nut itself is, the hull competes equally in terms of its potential benefits,

despite being overlooked. Understanding the worth of such by-products encourages their use in improving skin quality and incorporating them into daily routines.

The epicarp of the pistachio hull is approximately 1/16 of an inch thick and adheres tightly to the harder inner shell until the nut reaches maturity. Pistachio by-products have been reported to improve stability and nutritional characteristics in pharmaceutical applications, along with other remarkable health-promoting effects. They are also used as absorbents and are considered both economical and environmentally friendly options (Indurwade, N. H.).

Research highlights the antibacterial (Kashaninejad et al., 2006), anti-inflammatory, anti-melanogenic, and antioxidant properties of pistachio compounds (Barrea et al., 2016; Ersan et al., 2016). The aim of this study is to blend the powdered pistachio hull with selected wildflowers known for their medicinal and biological benefits, and to apply this combination externally as a protective layer.

These wildflowers are found in regions such as the Western Ghats and the Himalayas. The formulation serves as a defensive product for individuals living and working in wild and challenging environments, while also acting as a tribute to farmers. The selected wildflower, widely available in India, is Eulophia campestris, commonly known as Black Musalā or Salep Orchid. It belongs to the family Orchidaceae (Rajendran et al., 1997; Swapna, 2017). Several orchid species are traditionally used as herbal medicines. The Eastern Himalayas, Peninsular India, and the Andaman and Nicobar Islands are major orchid-rich regions in India, and the chosen species have been well documented for their medicinal value.

Methodology

This study was conducted to evaluate the preparation and application potential of pistachio hull powder for skin-related experimental use.

Collection of Samples

Fresh pistachio hulls were collected from local sources and thoroughly washed to remove impurities, ensuring their suitability for use as a primary raw material. A preliminary quality assessment of the raw materials was conducted prior to processing. The cleaned hulls were then allowed to air-dry for 2–3 days until they became sufficiently brittle for further preparation.

Preparation of Pistachio Hull Powder

After completion of the primary processing steps, the dried pistachio hulls were ground using a mechanical grinder and subsequently sieved to obtain a fine powder. The powder was passed through an 80–100 mesh sieve to ensure uniform particle size. This step was carried out with particular care, as fine particle consistency is essential to prevent skin abrasion during topical application. Any remaining coarse granules were further ground until a smooth, blendable powder was achieved, allowing effective mixing with the selected medicinal plant components.

Other Parameters

The formulation functions as a repellent lotion with a rinse-off applicator and exhibits a slurry-like texture. The essence of the Amarkand flower can be extracted for use in the formulation. Amarkand is a perennial plant known for its significant bioactive properties; however, thorough preliminary testing is essential before incorporating it into the experiment. The plant must meet specific safety, compatibility, and stability requirements to ensure its effectiveness when blended with other components, thereby preventing formulation failure during future applications. Consequently, rigorous evaluation and validation are required.

This plant-based repellent is highly recommended for individuals entering wild or forested environments, including field researchers. Its odour is difficult for animals and insects to detect, enhancing its repellent efficacy. In addition, this formulation is dedicated to farmers who work tirelessly in agricultural fields and

are encouraged to use the repellent blended with sandalwood (Santalum album) for enhanced protective and soothing effects.

Proportion

The ratios and calculations of the formulation must be carefully observed, as equal proportions cannot be used due to the distinct functional properties of each component. When 3 g of sandalwood powder is used, 1 g of pistachio hull powder is added as the estimated proportion, followed by the addition of water. The water is maintained at a 1:3 ratio, with approximately 5–6 mL added to achieve the desired consistency. The same proportioning approach is applicable when incorporating Amarkand to help control minor vector exposure. Pistachio hull possesses antihistaminic properties, which may help alleviate allergic reactions and skin rashes. When sandalwood powder is combined with pistachio hull powder and water, the formulation develops a mild brown colouration. This results in an oil-free preparation that requires no emulsifiers and offers an extended shelf life.

Application

The defense applicator is intended strictly for external use and requires prior evaluation before regular application. The extract can be customised based on individual needs and skin types. A patch test is strongly recommended before incorporating the product into a daily routine, especially for individuals with sensitive skin. Additional care should be taken to observe any changes or reactions that may occur after application. The appropriate variant should be selected and applied according to the environmental conditions of wild or forested areas, as the two variants are formulated with different base compositions. To prevent dust accumulation on the skin, this formulation is designed as a supportive skincare application for individuals engaged in prolonged outdoor or forest-based activities. It specifically addresses heat stress, dust-related irritation, and minor insect-associated skin discomfort.

Objective

This study aims to look beyond conventional cosmetic products and explore the value of pistachio hull, a commonly discarded agricultural by-product, as a natural material that can protect and comfort the skin. Instead of treating it as waste, the study views the pistachio hull as a simple, sustainable resource with practical skin-care potential.

The work focuses on preparing water-based slurry and seal formulations using pistachio hull powder combined with sandalwood and Amarkand (Eulophia campestris). These preparations are intentionally kept free from creams, oils, and synthetic additives, reflecting traditional methods where water alone is used to activate plant materials.

Another key objective is to observe how pistachio hull behaves when applied directly to the skin, especially in outdoor and forest-working environments where the skin is exposed to sunlight, dust, sweat, dryness, and continuous friction. The study aims to understand whether such a natural application can offer comfort, reduce irritation, and provide a protective layer under these demanding conditions.

The study also seeks to understand how pistachio hull works in combination with sandalwood, known for its cooling and calming nature, and Amarkand, traditionally valued for skin healing and renewal. Rather than focusing on cosmetic appeal, attention is given to how these materials interact on the skin in their most natural, water-activated form.

An important objective is to evaluate whether these simple formulations can act as a temporary skin seal or barrier, helping the skin retain moisture and defend itself against environmental stress without blocking natural skin functions.

Through this work, an effort is made to document and revive traditional and ethnobotanical knowledge related to these plant materials, while presenting the findings in a structured and scientific manner. This approach helps connect indigenous wisdom with modern research understanding.

Finally, the study aims to promote the idea of eco-friendly, low-cost, and culturally meaningful skin-care solutions that avoid synthetic chemicals and preservatives, offering a sustainable alternative that is both accessible and environmentally responsible.

Discussion

The pistachio hull-based skin seal was explored as a simple, water-activated protective layer rather than a cosmetic or moisturising product. When pistachio hull powder was mixed with water, it naturally formed a thin coating on the skin. This layer did not feel heavy or oily; instead, it created a subtle sense of coverage, suggesting that pistachio hulls can function as a temporary skin shield. The astringent nature of the hull appeared to gently tighten the skin surface, which may help reduce direct contact with dust, microbes, and environmental irritants, particularly during outdoor activities.

When sandalwood was added to the pistachio hull–water mixture, the sensory experience changed noticeably. The seal felt cooler and more balanced on the skin. Sandalwood appeared to soften the tightening effect of the pistachio hull while contributing a calming sensation. As the formulation dried, it remained evenly distributed without rapid cracking or flaking. This improved comfort during short-term use, especially in warm or humid conditions. Rather than nourishing the skin like a conventional cream, the formulation behaved more like a breathable herbal layer that could be easily washed off after use.

In contrast, the formulation containing Amarkand and water produced a different type of skin seal. While pistachio hull powder continued to provide the primary structure, Amarkand introduced a gentler and more soothing character. The resulting seal was softer and slightly flexible, making it feel less restrictive on the skin. This effect was particularly noticeable in areas exposed to heat or friction. The cooling sensation persisted for a longer duration, and the skin felt calmer even after the seal was removed. These observations suggest that Amarkand plays a significant role in enhancing skin comfort and tolerance rather than reinforcing the physical strength of the seal.

Overall, both formulations demonstrated that pistachio hull powder can serve as a strong base for developing non-moisturising, functional skin applicators. The sandalwood-based seal was more oriented toward cooling and environmental protection, whereas the Amarkand-based seal emphasised soothing and calming effects. Importantly, both systems remained simple, natural, and water-based, reinforcing the idea that effective skin protection does not necessarily require complex cosmetic formulations. These herbal skin seals highlight the potential of pistachio hulls as a sustainable and practical resource. By combining them with traditional botanicals such as sandalwood and Amarkand, it is possible to develop unique applicator systems that address specific functional needs, particularly for individuals working in outdoor or forest environments.

Properties and Compounds of Pistachio Hull

Table 1 Properties and Compounds of Pistachio Hull

Property	Major Compounds	Significance
Antioxidant	Polyphenols, Flavonoids, Gallic acid	Neutralises free radicals and protects skin cells from oxidative damage
Astringent	Tannins (hydrolysable & condensed)	Tightens skin surface and reduces excess oil secretion
Antimicrobial	Phenolic acids, Flavonoids	Inhibits growth of certain bacteria and fungi
Anti-inflammatory	Flavonoids, Terpenoids	Helps reduce irritation and inflammatory responses

UV-protective (mild)	Anthocyanins, Phenolics	Provides limited protection against UV-induced stress
Exfoliating (physical)	Lignocellulosic fibres	Aids in removal of dead skin cells when finely powdered
Antifungal	Phenols, Tannins	Suppresses fungal growth on skin surface
Cooling/Skin-comfort	Bioactive phenolics	Contributes to calming sensation when used with water-based formulations
Biodegradable & eco-friendly	Cellulose, Hemicellulose, Lignin	Supports sustainable and environmentally safe applications

Properties and Compounds of Eulophia campestris

Table 2 Medicinal Properties of Eulophia campestris (Amarkand)

Medicinal Property	What it Means in Simple Terms	How it Helps
Cooling property	The plant naturally reduces heat and burning sensations	Helps calm the skin and body during heat exposure or irritation
Demulcent property	Forms a soft, soothing layer due to its mucilage	Protects irritated or dry skin and reduces discomfort
Anti-inflammatory property	Reduces swelling and redness	Useful for minor skin irritation, inflammation, and soreness
Wound-healing property	Supports natural skin repair	Helps small cuts or abrasions heal faster and more comfortably
Antioxidant property	Protects cells from damage caused by stress and pollution	Maintains healthy skin and tissues
Skin-soothing property	Gives a calming and gentle feel when applied	Improves skin tolerance and comfort, especially in harsh environments
Rejuvenating (tonic) property	Traditionally believed to restore strength	Helps reduce fatigue and supports overall wellness
Protective property	Acts as a mild barrier on the skin	Shields skin from dust, friction, and environmental stress
Traditional medicinal use	Used in indigenous and Ayurvedic practices	Applied for heat-related disorders, weakness, and skin problems

Significance

The significance of this study lies in its effort to rethink how simple, naturally available materials can be used in meaningful and functional ways. Pistachio hulls, which are commonly discarded as agricultural waste, were explored not as by-products but as valuable natural resources. Through minimal processing and water-based activation, pistachio hull powder demonstrated the ability to form a temporary skin seal that provides protection, comfort, and easy removability. This approach represents an important shift in perspective, transforming waste materials into purpose-driven functional applications.

A major strength of this work is its non-cosmetic focus. Rather than emphasising beauty enhancement or long-term moisturisation, the formulations were designed as short-term functional skin applicators.

This makes them particularly relevant for individuals exposed to challenging environments, such as forest workers, agricultural labourers, and people working under dusty or high-temperature conditions. The skin-seal concept prioritises surface protection, cooling, and comfort, addressing practical, real-world needs instead of commercial cosmetic trends.

The inclusion of sandalwood and Eulophia campestris adds further depth to the study. Sandalwood contributed cooling and calming effects, helping to balance the astringent tightening action of pistachio hull tannins. Its presence improved overall comfort and made the formulation more pleasant to use, especially in warm environments. In contrast, Eulophia campestris introduced a softer and more soothing character. Traditionally recognised for its demulcent and cooling properties, Amarkand enhanced skin tolerance and flexibility of the seal, making it particularly suitable for sensitive or heat-exposed skin. The comparison between these two botanical combinations demonstrates how a single base material—pistachio hull powder—can be adapted to meet different functional requirements.

Another important aspect of this study is the exclusive use of water as the activating medium. By avoiding oils, emulsifiers, and synthetic additives, the formulations remain simple, biodegradable, and environmentally responsible. This water-based approach ensures easy removal, minimal residue, and a reduced risk of skin irritation. Such simplicity is often overlooked in modern product development, yet it proves highly effective in the present context.

From both academic and cultural perspectives, this work bridges traditional knowledge with experimental science. Botanicals such as sandalwood and Eulophia campestris have been used for centuries in indigenous and Ayurvedic practices for their cooling and healing properties. Incorporating these plants into a structured experimental framework provides scientific relevance to traditional practices and encourages their documentation and validation. This integration not only preserves cultural knowledge but also opens pathways for sustainable innovation.

The environmental significance of this study is equally noteworthy. By utilising pistachio hulls—an underexplored agro-waste material—the research supports sustainability and circular resource utilisation. Such approaches reduce waste generation, decrease reliance on synthetic materials, and promote eco-friendly alternatives.

Finally, this research serves as a foundation for future studies. The skin-seal concept can be further investigated for antimicrobial efficacy, duration of protection, user acceptability, and adaptability with other medicinal plants. It encourages future researchers to explore non-conventional formulation strategies and to focus on function-driven, human-centred applications rather than purely cosmetic solutions.

Conclusions

This study promotes simplicity and sustainability over excess complexity, prioritising function over appearance and blending traditional knowledge with scientific exploration. Transforming waste into a meaningful, finished product represents an ideal approach to value-driven innovation. The skin seals developed in this work emphasise comfort rather than beautification, making them particularly suitable for individuals working in outdoor or forest environments where practicality and ease of use are essential. Overall, this research highlights a sustainable, functional, and purpose-driven innovation that respects both nature and traditional wisdom.

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