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SUSTAINABLE BLACK LINGZHI COSMECEUTICAL DEVELOPMENT FOR COMMUNITY ECOTOURISM AND GRASSROOTS ECONOMIC RESILIENCE

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Abstract

This study investigates the sustainable development of high-value cosmeceuticals utilizing black Lingzhi (*Ganoderma lucidum*) from the Piyamit 1 ecotourism community in Thailand. To address regional economic vulnerabilities and a lack of distinctive local products, the research used a rigorous dual-extraction technique combining ethanol maceration and microwave-assisted water extraction. Comprehensive phytochemical analyses revealed that the resulting extract has remarkable biological properties, including high total phenolic content (378.28 mg GAE/g DW), potent antioxidant activity ($IC_{50} = 0.80$ mg/ml), significant tyrosinase inhibition, and strong antibacterial efficacy against key pathogens. Leveraging these bioactive polysaccharides and triterpenoids, researchers successfully formulated two highly stable, skin-compatible prototype products: a whitening facial cream and a cold-process facial soap. Both formulations showed excellent physical stability across multiple freeze-thaw cycles, strong moisture retention, and exceptionally high consumer satisfaction ratings. By systematically transforming indigenous biological resources into scientifically validated, premium cosmetic goods, this interdisciplinary initiative establishes a distinctive regional identity. Ultimately, this innovative model successfully integrates biodiversity conservation with experiential tourism, offering a highly replicable framework to strengthen grassroots economic resilience in rural Southeast Asian communities.

Keywords: *Ganoderma lucidum*, Cosmeceutical Development, Community-Based Ecotourism, Grassroots Economic Resilience, Bioactive Compounds

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Introduction

The Piyamit 1 community, in the Betong District of Yala Province, Thailand, is a significant ecotourism destination with invaluable biological resources, most notably the black Lingzhi mushroom (*Ganoderma lucidum*). This indigenous fungus thrives naturally in the pristine Hala-Bala Forest and is harvested annually between June and August using sustainable, conservative methods. Known for its chemical-free purity and prestigious image rooted in Traditional Chinese Medicine (TCM), black Lingzhi offers a unique opportunity for high-value commercialization (Namburi et al., 2023). Consequently, the research team identified the potential to elevate this local identity-based raw material into premium cosmetic products, aiming to address the community's lack of distinctive merchandise and meet the evolving demands of modern tourists.

From a cosmeceutical perspective, black Lingzhi is rich in potent bioactive compounds, specifically polysaccharides and triterpenoids, which show greater efficacy than common local herbs such as turmeric or aloe vera. These constituents provide broad antioxidant activity through multiple biological mechanisms (Sanodiya et al., 2009) and support sustained skin hydration and restoration. Unlike oil-based botanicals, these extracts function as Natural Moisturizing Factors (NMFs), significantly enhancing the skin's capacity to retain moisture. Phenolic compounds and kojic acid also inhibit tyrosinase activity, promoting a more radiant, even skin tone (Ahmad et al., 2021). Notably, the extract also demonstrates exceptional thermal and pH stability, which are critical parameters for superior cosmetic formulation development. This research focuses on systematically developing standardized, high-performance cosmetic prototypes from black Lingzhi extract to differentiate the product from conventional herbal products. The strategic upgrading of Hala-Bala's natural resources serves a dual purpose: it generates substantial added value for local raw materials. It creates a unique product identity that aligns with global natural cosmetic market trends. Ultimately, this initiative is designed to strengthen the grassroots economy and foster long-term sustainability for the Piyamit 1 community by integrating experiential tourism and commercializing high-quality, science-backed products.

Literature Review

Bioactive Profiles and Dermatological Mechanisms of *Ganoderma lucidum*

Ganoderma lucidum, commonly known as Lingzhi, has shifted from a cornerstone of Traditional Asian Medicine to a highly valued bioresource for advanced cosmeceutical applications because of its potent pharmacological properties. The mushroom is exceptionally rich in bioactive constituents, primarily categorized into polysaccharides and triterpenoids, which collectively offer profound dermatological benefits (Liang et al., 2019; Sánchez, 2017). The polysaccharides, predominantly β -D-glucans (Figure 1), act as powerful humectants that strengthen the skin barrier by reducing Transepidermal Water Loss (TEWL) and boosting Natural Moisturizing Factors (NMF) (Pillai et al., 2005). Furthermore, these polysaccharides neutralize reactive oxygen species (ROS) to provide photoprotection against UV radiation, stimulate fibroblasts to upregulate collagen synthesis (COL1A1 and COL3A1), and mitigate inflammation by inhibiting pro-inflammatory cytokines via the NF- κ B pathway (Fu et al., 2019; Sánchez, 2017).

Complementing these effects, over 60 lanostanoid triterpenoids—such as Ganoderic acids (Figure 2)—function through distinct mechanisms to preserve skin integrity. These small, lipophilic molecules absorb well through the skin, inhibit tyrosinase activity to reduce hyperpigmentation, and promote an even skin tone (Fu et al., 2019; Kligman, 2005). Additionally, triterpenoids show strong anti-allergic properties by suppressing histamine release and pro-inflammatory enzymes, while also preventing wrinkle formation by inhibiting matrix metalloproteinases (MMP-1 and MMP-3) that degrade collagen and elastin (Boh et al.,

2007; Liang et al., 2019). Transforming these raw extracts into viable commercial products demands strict adherence to cosmeceutical principles, requiring rigorous safety validations, including irritation and patch tests, and maintaining formulation stability within an optimal pH range of 4.5 to 7.0, fully compliant with ISO 22716:2007 Good Manufacturing Practices (Kligman, 2005; Wu et al., 2016).

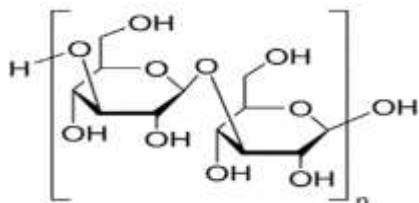


Figure 1 Structure of β -D-glucan

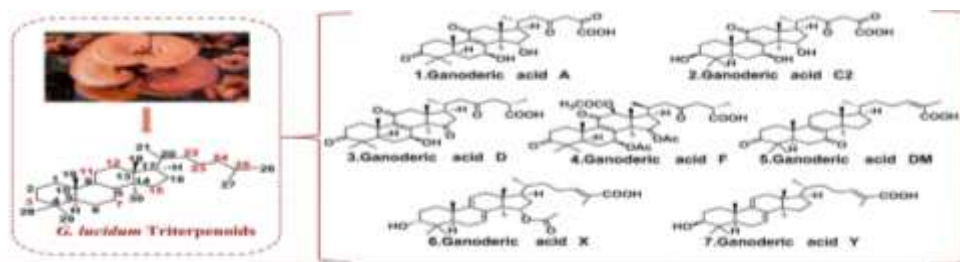


Figure 2 Structure of Ganoderic Acid

Strategic Cosmeceutical Innovation and Market Dynamics

Transforming indigenous Lingzhi from a traditional botanical supplement into an advanced cosmeceutical aligns with the "Innovative Product" classification outlined by Fuller (2011). This strategic commercialization embodies Sustainable Tourism principles by balancing resource use with community income generation and ecological preservation (World Tourism Organization, 2005). Furthermore, using locally sourced, naturally grown Lingzhi from the Hala-Bala Forest gives community enterprises a distinct, sustainable competitive advantage, a concept firmly supported by the Resource-Based View (Barney, 1991). Across the broader East Asian cosmetic industry—particularly in Japan, South Korea, and China—mushroom extracts are widely used for their potent anti-aging and skin-rejuvenating properties (Wu et al., 2016). Recent cosmeceutical research consistently validates *Ganoderma lucidum* formulations; for instance, ethanolic extracts rich in ganoderic acid retain significant bioactivity and skin-compatible pH levels when incorporated into creams (Taofiq et al., 2017), while aqueous extracts in facial cleansers successfully enhance skin hydration without inducing oxidative toxicity (Sharma, 2026). Collectively, these findings validate black Lingzhi as a high-potential source of bioactive ingredients for developing safe, effective, and globally competitive natural cosmeceuticals.

Research Conceptual Framework

The conceptual framework of this study, as illustrated in Figure 3, outlines the systematic progression of transforming indigenous *Ganoderma lucidum* from the Piyamit 1 community into high-value cosmeceutical products. It highlights an interdisciplinary approach that integrates local cultural and natural ecotourism heritage with advanced bioactive extraction and cosmetic product development. This integration channels natural bioresources into premium prototypes—specifically a whitening facial cream and a facial soap—designed to promote experiential tourism, generate sustainable income, and ultimately foster grassroots economic resilience within the community.

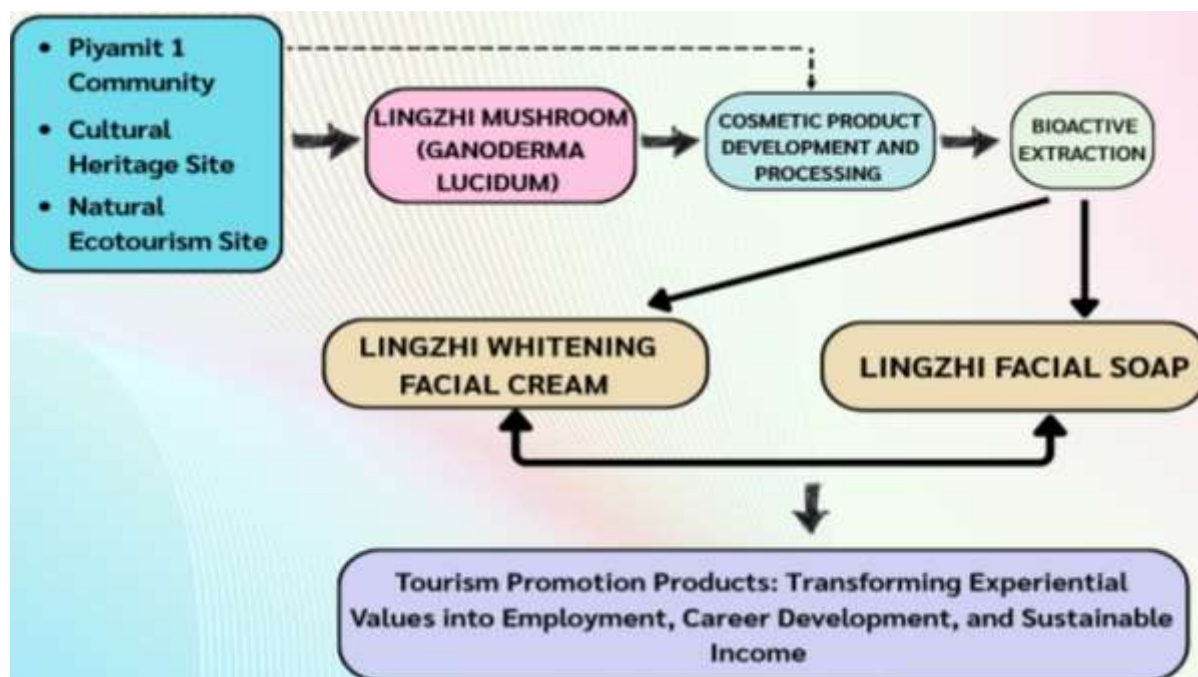


Figure 3 Research Framework

Community Engagement and Experimental Design

This study used a sequential mixed-methods approach, beginning with semi-structured focus group interviews with 30 participants from the Piyamit 1 community in Tano Maero Subdistrict, Betong District, Yala Province. This preliminary phase aimed to assess grassroots needs for processing Lingzhi mushrooms into value-added commercial products and provide the rationale for subsequent product development. We processed qualitative data from these observations using rigorous content analysis, and evaluated quantitative experimental data for statistical significance using Analysis of Variance (ANOVA). To ensure reliability and reproducibility across all developmental phases, we established comprehensive chemical, biological, and product-level controls. We performed all experiments in triplicate ($n = 3$), using standard bioactive compounds as positive controls against pure solvent baselines. The research methodology strictly adhered to ethical standards and secured Human Research Ethics Approval from Yala Rajabhat University (Project Code: Soc-1-2567-008).

Extraction Protocols and Analytical Procedures

The laboratory-based product development focused on a sophisticated dual-extraction technique to maximize bioactive yield. Specifically, Microwave-Assisted Extraction (MAE) used water as the primary solvent, controlled at 60-80°C and 1-2 bar for 10-15 minutes at 400-600 Watts, maintaining a solid-to-solvent ratio of 1:20 (w/v). After this phase, the filtrate was combined with an ethanolic extract, concentrated via a rotary evaporator at 40-50°C, and then freeze-dried to produce a potent, dark-brown concentrated powder. The team conducted these extraction protocols and raw material preparations at the Natural Products Chemistry Laboratory of Maejo University Phrae Campus, while advanced physicochemical analyses and chemical profiling—using a BioTek Synergy™ H1 Multi-Mode Microplate Reader—were performed at the Cosmetic Science and Microbiology Laboratories of Yala Rajabhat University.

Results

Phytochemical Yield and Antimicrobial Potency

The dual extraction technique—integrating ethanolic maceration with microwave-assisted water extraction—yielded a concentrated dark brown powder representing a 9.56% extraction efficiency (286.7 g). Advanced chemical profiling confirmed a robust polysaccharide content of 74.88% alongside an exceptional total phenolic content (TPC) of 378.28 mg GAE/g DW. The extract showed potent biological activity, with strong antioxidant capacity (DPPH IC₅₀ = 0.80 mg/ml) and 35% tyrosinase inhibition relative to the standard kojic acid, indicating strong melanogenesis-inhibitory potential. Furthermore, agar disc diffusion assays confirmed the extract's significant antimicrobial efficacy at 500 mg/ml, effectively generating prominent clear zones against *Bacillus cereus* (9 ± 0 mm), *Escherichia coli* (9 ± 0 mm), and *Staphylococcus aureus* (7 ± 0 mm) (as detailed in Table 1).

Table 1 Antimicrobial Activity of Lingzhi Extract Using the Agar Disc Diffusion Method

Test Bacteria	Clear Zone Diameter (mm)		
	Lingzhi Extract (500 mg/ml)	10% DMSO	Tetracycline
<i>Bacillus cereus</i>	9 ± 0	NA	25.66 ± 0.57
<i>Staphylococcus aureus</i>	7 ± 0	NA	34.66 ± 0.57
<i>Escherichia coli</i>	9 ± 0	NA	24.33 ± 0.57

Note: NA = No Activity.

Prototype Formulation, Stability, and Consumer Evaluation

Leveraging the extract's robust bioactive profile, the research successfully formulated two primary prototypes: a whitening facial cream and a cold-process facial soap (illustrated in Figures 4 and 5). The whitening cream exhibited a fine, glossy texture with a pale cream hue, excellent flow properties, and an optimal skin-compatible pH of 5- 6, showing complete resistance to microbial or fungal contamination (Table 2). Rigorous stability testing via six Freeze-Thaw cycles (alternating between 4°C and 45°C for 48 hours each) confirmed the cream's structural integrity, maintaining its formulation without any phase separation, creaming, or cracking (Tables 3 and 5). In sensory evaluations, the cosmetic prototype achieved an 'Excellent' desirability rating, with users specifically highlighting its rapid absorption, prolonged hydration, and non-greasy finish (Table 4). Concurrently, the formulated facial soap demonstrated ideal physicochemical properties, recording a pH of 9.43 ± 0.04, a substantial foaming ability of 9.54 ± 0.23 cm, and an effective solubility rate of 17.23 ± 1.75 minutes (Table 6).



Figure 4 Lingzhi Whitening Facial Cream



Figure 5 Lingzhi Facial Soap

Table 2 Physicochemical Evaluation of Lingzhi Whitening Facial Cream

Parameters	Evaluation Results
Texture	Fine, glossy
Color	Pale cream
Odor	Subtle mushroom extract and fragrance
Flow Property	Excellent (++++)
Creaming/Cracking	None observed
pH Level	5-6
Microbial/Fungal Growth	None detected

Table 3 Stability Evaluation of Lingzhi Whitening Facial Cream

Temperature	Stability Results
4°C	Stable, no physical alteration
45°C	Stable, no physical alteration

Table 4 Sensory Evaluation of Lingzhi Whitening Facial Cream

Parameters	Evaluation Results
Skin Absorption	Excellent absorption, soft and hydrated feel
Non-greasiness	Easy to apply, non-sticky, comfortable
Color	Pale cream, visually appealing
Desirability	++++ (Excellent)

Table 5 Comparative Physicochemical and Stability Properties at t = 0 and t = 6 Cycles

Parameters	t = 0 (Room Temp)	t = 6 cycles (Stability Test)
Texture	Fine, glossy	Fine, glossy
Color	Pale cream	Cream
Odor	Fragrant	Fragrant
Flow Property	++++	+++
Creaming/Cracking	None	None
pH Level	6	6
Microbial Growth	None	None
Application Feel	Smooth, rapid absorption	Smooth, moderate absorption
Desirability	++++ (Excellent)	+++ (Very Good)

Table 6 Physicochemical Properties of Lingzhi Facial Soap

Parameters	Results
pH Level	9.43 ± 0.04
Foaming Ability (cm)	9.54 ± 0.23
Solubility/Hardness (min)	17.23 ± 1.75

Conclusion and Discussion

Bioactive Profiling and Formulation Efficacy

Community surveys clearly indicated strong regional demand for affordable, Lingzhi-based skincare products with a distinct local identity suitable for diverse tourist demographics. To address this need, the research successfully formulated two prototype cosmeceuticals: a whitening facial cream designed to promote a radiant complexion for sensitive skin, and a facial soap enriched with Vitamin E and Lingzhi extract for deep, gentle cleansing. The dual extraction technique—combining ethanolic maceration with Microwave-Assisted Extraction (MAE)—proved highly efficient, yielding a concentrated extract with 74.88% total sugar

content and an exceptional Total Phenolic Content (TPC) of 378.28 mg GAE/g DW. Furthermore, the extract's robust antioxidant capacity, demonstrated by a DPPH assay IC₅₀ of 0.80 mg/ml, closely corroborates the findings of Jaricksakulchai et al. (2023), who reported a comparable IC₅₀ of 0.78 mg/ml for red Lingzhi root extracts. Using gentle, cosmetic-grade ingredients, the resulting whitening cream had a fine, glossy texture, an optimal skin-compatible pH (5-6), and rapid absorption, ultimately earning an 'Excellent' desirability rating in sensory assessments.

Antimicrobial Potency and Formulation Stability

Beyond its antioxidant properties, the Lingzhi extract showed strong antimicrobial efficacy, inhibiting key pathogens including *Bacillus cereus*, *Staphylococcus aureus*, and *Escherichia coli* at 500 mg/ml. These results align with Srithaworn et al. (2019), confirming that higher concentrations of phenolic and flavonoid compounds correlate with stronger antibacterial activity. Mercan et al. (2006) further supported this conclusion by identifying a strong direct correlation between antibacterial potency, antioxidant activity, and total phenolic content in medicinal fungal extracts. Crucially, the prototype formulations showed strong physical integrity: a 10% extract lotion remained stable under ambient and accelerated conditions without phase separation, while the facial cream withstood six rigorous Freeze-Thaw cycles at 4°C and 45°C without creaming, cracking, or microbial contamination. Concurrently, the formulated facial soap achieved optimal physicochemical parameters, including a pH of 9.43, a foaming capacity of 9.54 cm, and an effective solubility rate.

Socio-Economic Implications for Ecotourism

By systematically transforming raw indigenous resources into high-value, scientifically validated cosmeceuticals, this initiative provides a strategic blueprint for grassroots economic resilience. Target communities and relevant government agencies should scale up these production processes to diversify the regional product portfolio and meet the evolving demands of modern experiential tourism. At the same time, researchers should further investigate various *Ganoderma* species to expand these product ranges into specialized categories, such as advanced hair care series. Ultimately, adopting this standardized extraction and formulation methodology will foster sustainable career opportunities, drive local income generation, and successfully integrate biodiversity conservation with socio-economic development within rural communities.

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Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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