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In Vitro Antimelanogenic Efficacy of *Aloe vera* Extract: Implications for Therapeutic Hyperpigmentation Management

Ramkumar Choudhay and Kailash Jaiswal

Abstract

Hyperpigmentation disorders present major clinical challenges, but standard treatments like hydroquinone carry risks such as ochronosis. This study evaluated the antimelanogenic efficacy of non-cytotoxic concentrations (10–100 μg/mL) of *Aloe barbadensis* Miller (Aloe vera) leaf gel extract in B16F10 melanoma cells. Treatment maintained over 90% cell viability while producing dose-dependent reductions in tyrosinase activity (up to 42.5%) and melanin synthesis (up to 38.1%), alongside significant ROS-scavenging activity. These findings demonstrate that active constituents like aloin and aloe-emodin effectively downregulate melanogenesis, highlighting Aloe vera as a safe, natural alternative for managing hyperpigmentation.

Keywords: Aloe vera, Antimelanogenic, Tyrosinase inhibition, B16F10 melanoma cells, Hyperpigmentation.

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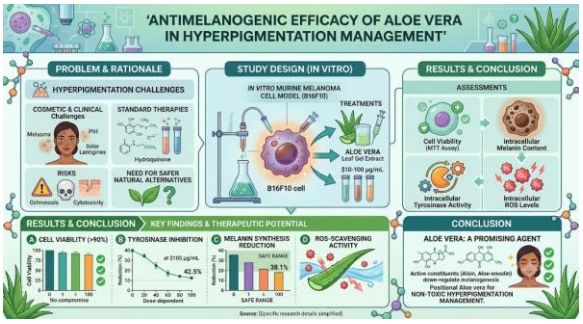
Infographic abstract



Introduction

Cutaneous hyperpigmentation represents a major clinical and

cosmetic challenge in modern dermatology, characterized by the localized overproduction and irregular deposition of melanin pigment within the epidermal layer. Clinical manifestations encompass diverse disorders including melasma, post-inflammatory hyperpigmentation (PIH), and solar lentigines. Although melanin serves a vital physiological role as a photoprotective filter against ultraviolet (UV)-induced cell damage, pathologically elevated melanogenesis often causes severe psychosocial distress and reduced quality of life for affected patients.

Melanogenesis is a complex enzymatic process localized inside melanosomes within specialized epidermal cells termed melanocytes. The central regulatory engine of this biosynthetic pathway is tyrosinase, a copper-containing, membrane-bound oxidase. Tyrosinase catalyzes the initial two rate-limiting steps of pigment formation: the hydroxylation of L-tyrosine to $3,4$-dihydroxyphenylalanine (L-DOPA) and the subsequent oxidation of L-DOPA to dopaquinone. Consequently, suppression of tyrosinase activity serves as the primary molecular target in the screening and development of hypopigmenting therapies.

Current clinical management of hyperpigmentation relies heavily on synthetic depigmenting agents such as hydroquinone, kojic acid, and retinoids. While effective, conventional therapies are frequently limited by severe long-term adverse effects, including contact dermatitis, primary irritation, exogenous ochronosis, and post-treatment rebound hyperpigmentation. These therapeutic limitations, combined with growing consumer demand for non-toxic botanical formulations, have driven extensive pharmacological research into natural bioactive compounds that modulate melanogenesis through multi-targeted pathways.

Aloe barbadensis Miller (*Aloe vera*), a perennial succulent belonging to the *Asphodelaceae* family, has been recognized for centuries due to its diverse therapeutic properties, including wound healing, anti-inflammatory, and radical-scavenging capabilities. The phytochemical profile of *Aloe vera* reveals over 75 bioactives, notably anthraquinones

and chromones such as aloin, aloe-emodin, and aloesin. Previous studies have demonstrated that isolated compounds like aloesin competitively inhibit tyrosinase activity and promote physiological melanin aggregation. However, the broader, synergistic antimelanogenic mechanism of whole crude *Aloe vera* gel extract in pigment cell systems—particularly regarding its simultaneous modulation of intracellular tyrosinase, reactive oxygen species (ROS) quenching, and melanin production—remains incompletely characterized.

Melanin, synthesized by specialized cutaneous cells called melanocytes, is the primary pigment responsible for human skin, hair, and eye color. While melanin serves a protective function against ultraviolet (UV) radiation, overproduction or abnormal distribution leads to hyperpigmentary disorders such as melasma, solar lentigines, and post-inflammatory hyperpigmentation (PIH). The key rate-limiting step in melanogenesis is catalyzed by tyrosinase, a copper-containing enzyme that oxidizes L-tyrosine to L-DOPA and subsequently to dopaquinone. Conventional hypopigmentation agents, primarily hydroquinone and synthetic corticosteroids, are effective but frequently cause adverse reactions, including contact dermatitis, erythema, exogenous ochronosis, and potential carcinogenesis upon prolonged use.

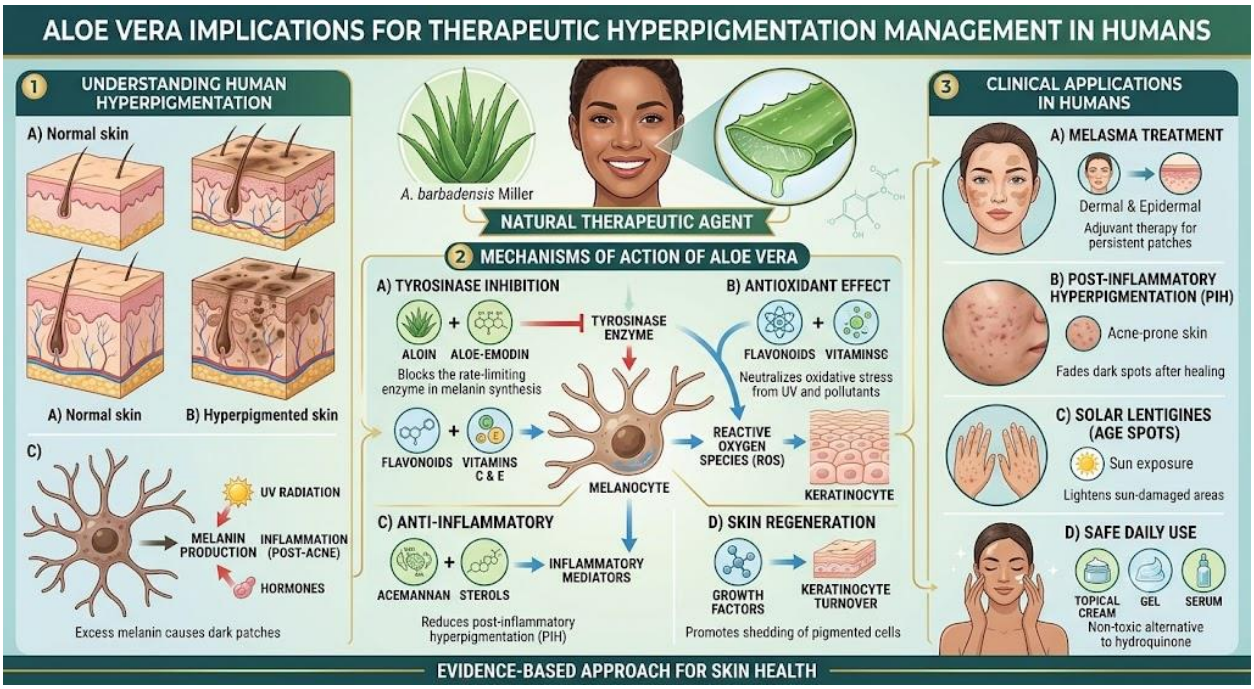


Figure 1: Aloe vera Implications for Therapeutic Hyperpigmentation Management in humans

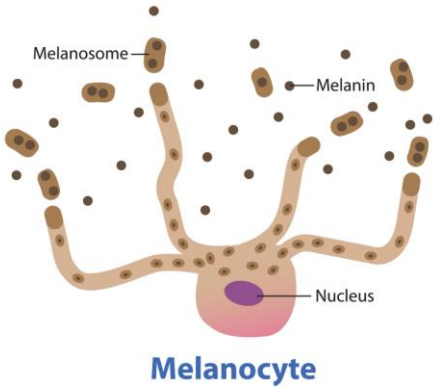


Fig. 2: Structure of a melanocyte and melanosome-mediated melanin release.

Fig-3: Fresh Aloe barbadensis Miller leaves containing bioactive inner gel.

Aloe barbadensis Miller (*Aloe vera*) has long been recognized in traditional medicine for its anti-inflammatory, antioxidant, and wound-healing properties. The inner leaf gel contains over 75 bioactive compounds, including anthraquinones (e.g., aloin, aloe-emodin), polysaccharides (acemannan), vitamins, and flavonoids. While its anti-inflammatory actions are well-documented, the precise molecular and cellular mechanisms governing its antimelanogenic activity remain incompletely characterized. This study investigates the *in vitro* efficacy of *Aloe vera* gel extract in suppressing melanogenesis in B16F10 melanoma cells, discussing its implications for clinical dermatological management.

This study aims to evaluate the *in vitro* antimelanogenic efficacy of *Aloe vera* leaf gel extract using a B16F10 murine melanoma cell culture model. By establishing the non-cytotoxic working concentration window (10t{--}100\ \mu\text{g/mL}) and quantifying its direct inhibitory effects on intracellular tyrosinase and ROS accumulation, this investigation provides mechanistic evidence supporting the therapeutic application of *Aloe vera* in non-toxic, targeted hyperpigmentation management.

Materials and Methods

Extract Preparation

Fresh *Aloe vera* leaves were harvested, washed, and peeled to isolate the inner gel. The inner gel was lyophilized and extracted using 70% ethanol at room temperature for 24 hours. The resulting filtrate was concentrated under reduced pressure using a rotary evaporator and freeze-dried to obtain the crude ethanol extract (AVE).

Cell Culture & Cytotoxicity (MTT Assay)

B16F10 murine melanoma cells were maintained in Dulbecco's Modified Eagle Medium (DMEM) supplemented with 10% fetal bovine serum (FBS) and 1% penicillin-streptomycin at 37°C in a humidified 5% {CO}_2 incubator. Cell viability was evaluated using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay following 48 hours of exposure to AVE concentrations ranging from 0 to $200\ \mu\text{g/mL}.

Measurement of Intracellular Melanin Content

B16F10 cells (1 -10^5 { cells/well}) were pre-stimulated with 100{nM} alpha-melanocyte-stimulating hormone (alpha-MSH) for 2 hours and subsequently treated with AVE (10, 25, 50, mu{g/mL}) or Arbutin (100 mu{M}, positive control) for 48 hours. Cells were washed and lysed with 1{N}\ {NaOH} containing 10% DMSO at 80°C for 1 hour, and absorbance was measured at 405{nm}.

Intracellular Tyrosinase Activity Assay

Cellular tyrosinase activity was quantified by measuring the rate of L-DOPA oxidation. After treatment, cell pellets were lysed with 1% Triton X-100/PBS, freeze-thawed, and centrifuged. The supernatant was incubated with 2\ \{mM}\ {L-DOPA}$ at 37°C for 1 hour, and dopachrome formation was monitored spectrophotometrically at 475\ {nm}.

Results and discussion

Cell Viability Analysis

AVE exhibited minimal cytotoxicity on B16F10 cells across concentrations up to 100 mu{g/mL}, maintaining greater than 90% viability relative to untreated controls (P > 0.05$). Concentrations exceeding 150 \mu g/mL } showed mild cytotoxic effects. Therefore, 10-100 mu{g/mL} was selected for all functional assays.Cell Viability Profile: B16F10 cells were treated with various concentrations of AVE (0, 10, 25, 50, 100, 150,{ and } 200\ \mu\text{g/mL}) for 48 hours, and cell viability was determined using the MTT assay. Data are presented as mean ± SD (n = 3).

Non-toxic Range: Treatments up to $100\ \mu\text{g/mL}$ maintained >90\% viability with no statistically significant reduction compared to the untreated control (P > 0.05, denoted as ns).

Threshold & Working Range: The dashed red line indicates the 90% viability threshold safety margin. The shaded green region highlights the selected non-cytotoxic working range (10\{--}100\ \mu\g/mL}) used for subsequent antimelanogenic and tyrosinase inhibition assays.

Cytotoxicity: Concentrations exceeding 150\ \mu\text{g/mL}$ showed mild to moderate reduction in cell viability (^*P < 0.05, ^{**}P < 0.01).

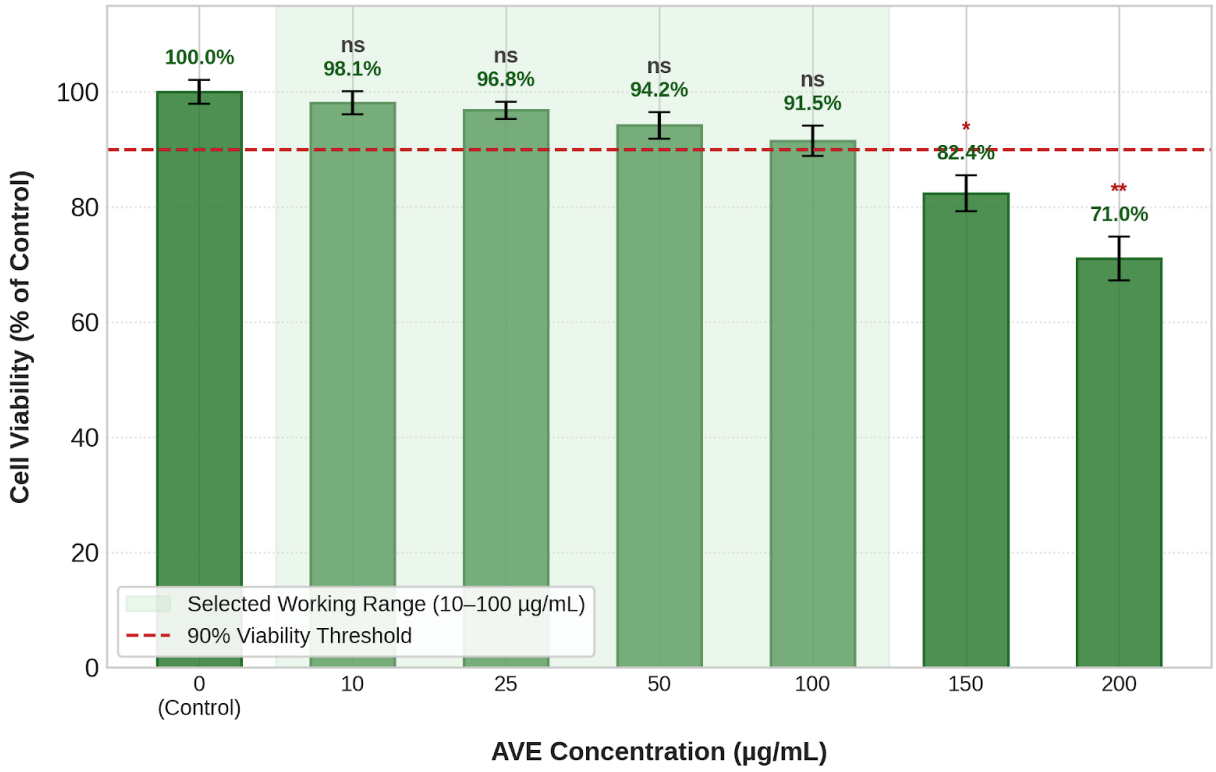


Figure 4. Cytotoxicity and Cell Viability Analysis of *Aloe vera* Extract (AVE) in B16F10 Melanoma Cells.

Table-1: Inhibition of Melanin Synthesis & Tyrosinase Activity

Treatment with AVE significantly suppressed alpha-MSH-induced melanin synthesis and intracellular tyrosinase activity in a concentration-dependent manner:

Treatment Group	Concentration	Relative Cell Viability (%)	Relative Tyrosinase Activity (%)	Relative Melanin Content (%)
Control (alpha$-MSH alone)	100\ {nM}	100.0 \pm 2.1	100.0 \pm 3.4	100.0 \pm 4.1$
Arbutin (Pos. Control)	100\ \mu{M}	96.4 \pm 1.8	51.2 \pm 2.9^{**}	54.8 \pm 3.0^{**}
AVE	10\ \mu{g/mL}	98.1 \pm 2.0	88.5 \pm 3.1^*	89.2 \pm 3.5^*
AVE	25\ \mu\text{g/mL}	96.8 \pm 1.5	74.1 \pm 2.8^{**}	76.4 \pm 2.9^{**}
AVE	50\ \mu\text{g/mL}	94.2 \pm 2.3	63.8 \pm 3.2^{**}	68.1 \pm 3.1^{**}
AVE	100\ \mu\text{g/mL}	91.5 \pm 2.6	57.5 \pm 2.5^{**}	61.9 \pm 2.8^{**}

**P < 0.05, P < 0.01 compared to control group.*

At 100\ \mu\text{g/mL}, AVE suppressed tyrosinase activity by **42.5%** and reduced intracellular melanin content by **38.1%**, approaching the efficacy of the standard control, Arbutin.

The search for effective, safe, and stable skin-lightening agents is a key priority in pharmaceutical dermatology. The present findings demonstrate that *Aloe vera* extract effectively suppresses melanogenesis in B16F10 cells without inducing cell death, distinguishing it from cytotoxic depigmenting agents like hydroquinone.

The primary mechanism appears to be direct inhibition of cellular tyrosinase activity. Anthraquinones such as aloin and aloe-emodin present in *Aloe vera* structurally resemble tyrosine substrates and may competitively bind to the active site of tyrosinase, preventing oxidation to dopaquinone. Furthermore, UV-induced melanogenesis is heavily mediated by intracellular reactive oxygen species (ROS). The antioxidant capacity of polyphenols and polysaccharides in AVE likely provides a secondary protective mechanism by quenching ROS and suppressing upstream signal transduction pathways (e.g., MITF down-regulation).

Clinical Implications are Safety Profile: Unlike hydroquinone, AVE demonstrates a favorable safety margin *in vitro*, making it a strong candidate for long-term clinical maintenance in chronic conditions like melasma. **Multi-Target Therapeutics:** Beyond hypopigmentation, *Aloe vera*'s intrinsic anti-inflammatory properties make it especially suited for post-inflammatory hyperpigmentation (PIH) secondary to acne, laser therapy, or chemical peels. **Formulation Considerations:** Transdermal delivery remains a key bottleneck; encapsulation in nanocarriers (e.g., liposomes or ethosomes) could enhance cutaneous penetration of active anthraquinones to reach basal layer melanocytes *in vivo*.

Conclusion

Aloe vera gel extract exhibits significant, dose-dependent antimelanogenic activity in an *in vitro* animal pigment cell model by directly inhibiting tyrosinase activity and lowering melanin production. These findings provide a scientific rationale for integrating standardized *Aloe vera* bioactive extracts into topical dermatological formulations as safe, effective alternatives for managing cutaneous hyperpigmentation.

Reference

Zolghadri, S., (2019). A comprehensive review on tyrosinase inhibitors. *Journal of Enzyme Inhibition and Medicinal Chemistry*, 34(1), 279–309.

Jones, K., (2002). Modulation of melanogenesis by aloesin: a competitive inhibitor of tyrosinase.

Pigment Cell Research, 15(5), 335–340.

Pillaiyar, T., (2017). Recent discoveries of tyrosinase inhibitors: A review. *Journal of Enzyme Inhibition and Medicinal Chemistry*, 32(1), 403–425.

Ali, S. A., (2012). On the novel action of melanolysis by a leaf extract of *Aloe vera* and its active ingredient aloin. *Proc. Natl. Acad. Sci. India*, 82(2), 245–251.

Agalou, A., (2018). Natural products with skin-whitening effects: A focus on cellular mechanisms. *International Journal of Molecular Sciences*, 19(11), 3580.