

Oligomeric Proanthocyanidin-Enriched Maritime Pine Bark Microcapsules Modulate Melanogenesis-Related Endpoints: Evidence for Pigmentation Balance and Skin-Tone Uniformity

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Citation: Mouad, B., Lawson, H. Bennet, L. Oligomeric Proanthocyanidin-Enriched Maritime Pine Bark Microcapsules Modulate Melanogenesis-Related Endpoints: Evidence for Pigmentation Balance and Skin-Tone Uniformity. American Journal of Biology and Natural Sciences 2026, 3(9), 151-156.

Received: 5th Aug 2026

Revised: 20th Aug 2026

Accepted: 4th Sep 2026

Published: 24th Sep 2026



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Abstract: Melanogenesis is influenced by α -MSH signaling, oxidative stress and communication between melanocytes and neighboring skin cells. We tested a BCLC maritime pine bark microcapsule enriched in DP2-DP6 oligomeric proanthocyanidins in an α -MSH-stimulated B16-F10 model and compared the experimental endpoints with published human pigmentation studies. The reference BCLC material contained 62.4% DP2-DP6 within total proanthocyanidins. At 25, 50 and 100 μ g/mL, relative melanin content was 91.6%, 84.7% and 78.9% of the α -MSH model; tyrosinase activity was 93.5%, 88.6% and 82.5%, and cell viability remained 93.8-97.8%. Human research with French maritime pine bark extract includes a randomized crossover study of seasonal skin darkening, a randomized placebo-controlled melasma study that measured mMASI and colorimetric contrast, and a randomized study of age-spot pigmentation. A 2026 pilot using a combined Pycnogenol-pomegranate product also reported lower melanin index and higher L* values. The cell data and the established clinical measurement methods support BCLC-specific testing of pigmentation balance and skin-tone uniformity.

Keywords: pigmentation; melanogenesis; tyrosinase; maritime pine bark; oligomeric proanthocyanidins; skin tone; melanin index

Introduction

Melanin output is controlled by α -MSH/MITF signaling, tyrosinase activity, melanosome handling and signals from keratinocytes. Light exposure and oxidative stress can alter this network. Maritime pine bark extracts contain procyanidins with antioxidant and anti-inflammatory activity described in experimental and clinical reviews [1]-[4]. Melanogenesis has also been examined directly: pine bark extract has reduced melanin production or tyrosinase activity in B16 cells and cultured human melanocytes under defined experimental conditions [5], [6].

Human skin studies provide several useful pigmentation endpoints. In 76 outdoor workers, Zhao et al. used a randomized double-blind crossover design and reported protection against

seasonal skin darkening during 100 mg/day supplementation [7]. Lima et al. studied 44 women with melasma and found a larger reduction in mMASI and colorimetric contrast when oral pine bark extract was added to standardized topical therapy [8]. Furumura et al. measured reduced pigmentation of age spots in 112 women with photoaged skin [9]. Earlier work also examined melasma after oral Pycnogenol [10], while Saliou et al. used MED as a direct UV-response measure [11].

The BCLC ingredient narrows the chemical specification before these skin endpoints are considered. It enriches DP2-DP6 oligomers, reduces catechin/epicatechin and high-polymer tannins, and uses microencapsulation to improve stability. Human pharmacokinetic studies show that maritime-pine-derived compounds and metabolites appear after oral dosing [12], and procyanidin absorption and metabolism vary with degree of polymerization [13]. The experiment therefore focused on a simple question: how a DP2-DP6-defined BCLC preparation changes melanin and tyrosinase responses in the α -MSH model, with published human work used to select clinically relevant measurements rather than to substitute for formulation-specific evidence.

Materials and Methods

1. Test ingredient. The BCLC maritime pine bark extract was prepared by staged resin fractionation, two-stage membrane separation and composite-wall microencapsulation. The reference formulation contained $74.8 \pm 2.1\%$ total proanthocyanidins; $62.4 \pm 1.8\%$ of total proanthocyanidins were DP2-DP6, catechin plus epicatechin was $5.1 \pm 0.4\%$, and $DP \geq 10$ material was $7.3 \pm 0.6\%$.
2. B16-F10 melanogenesis model. B16-F10 cells were stimulated with α -MSH. BCLC extract was applied at 25, 50 and 100 $\mu\text{g/mL}$ for the defined incubation period. Cell viability, melanin content and tyrosinase activity were measured. Melanin and tyrosinase values were normalized to the α -MSH model group (100%). Arbutin at 200 μM served as the positive comparator.
3. Evidence search. PubMed/PMC and publisher resources were searched through August 2026 for maritime pine bark, Pinus pinaster, Pycnogenol, pigmentation, melasma, skin darkening, L^* value, colorimetry, melanin index and randomized trials. Human studies were separated by design and by whether pine bark was used alone or in combination with other active ingredients.

Results

1. Cell viability and melanin. The α -MSH model maintained $100.0 \pm 3.4\%$ viability and was normalized to $100.0 \pm 3.5\%$ melanin. BCLC at 25, 50 and 100 $\mu\text{g/mL}$ maintained viability at $97.8 \pm 3.0\%$, $95.9 \pm 2.9\%$ and $93.8 \pm 2.8\%$; melanin was $91.6 \pm 3.0\%$, $84.7 \pm 2.8\%$ and $78.9 \pm 2.6\%$.
2. Tyrosinase activity. Tyrosinase activity was $93.5 \pm 3.1\%$, $88.6 \pm 2.7\%$ and $82.5 \pm 2.5\%$ at 25, 50 and 100 $\mu\text{g/mL}$. At 100 $\mu\text{g/mL}$, the ordinary extract comparator gave melanin and tyrosinase values of $90.8 \pm 3.1\%$ and $92.4 \pm 3.0\%$, respectively.
3. Clinical pigmentation context. In a randomized double-blind crossover trial of 76 outdoor workers, 100 mg/day standardized pine bark extract for 12 weeks protected against seasonal skin darkening and also supported hydration and barrier parameters [7]. Lima et al. compared 75 mg pine bark extract twice daily with placebo for 60 days in 44 women with facial melasma; both groups also received sunscreen and triple-combination topical therapy. The pine-bark group showed a larger mean reduction in mMASI and greater improvement in colorimetric contrast [8]. Furumura et al. reported reduced pigmentation of age spots during oral pine bark supplementation in 112 women with photoaged skin [9]. A 2026 single-arm pilot of a combined Pycnogenol and pomegranate product in ten Indian adults reported reductions in melanin index and increases in L^* after four weeks [14].

Table 1. B16-F10 melanogenesis response

Group	Concentration	Cell viability (%)	Melanin (% of model)	Tyrosinase (% of model)
Blank control	0	100.0±3.1	59.4±2.4	63.7±2.6
α-MSH model	0	100.0±3.4	100.0±3.5	100.0±3.4
Ordinary extract comparator	100 µg/mL	94.6±2.9	90.8±3.1	92.4±3.0
BCLC low	25 µg/mL	97.8±3.0	91.6±3.0	93.5±3.1
BCLC medium	50 µg/mL	95.9±2.9	84.7±2.8	88.6±2.7
BCLC high	100 µg/mL	93.8±2.8	78.9±2.6	82.5±2.5
Arbutin	200 µM	91.5±2.7	64.2±2.3	68.4±2.4

Table 2. Human evidence relevant to pigmentation and skin-tone endpoints

Study	Design / population	Exposure	Pigmentation-related observation
Zhao et al., 2021 [7]	Randomized double-blind placebo-controlled crossover; n=76 outdoor workers	100 mg/day; 12 weeks	Protected against seasonal skin darkening; skin barrier/hydration benefits also reported
Lima et al., 2021 [8]	Randomized double-blind placebo-controlled; n=44 women with melasma	75 mg twice daily; 60 days, alongside standardized topical therapy	Greater reduction in mMASI and colorimetric contrast versus placebo
Furumura et al., 2012 [9]	Randomized oral supplementation study; n=112 women with photoaging	40 or 100 mg/day depending study arm	Age-spot pigmentation reduced by skin-color measurement
Arunachalam, 2026 [14]	Single-arm pilot; n=10; combined Pycnogenol+pomegranate	50 mg Pycnogenol + 187.5 mg pomegranate/day; 4 weeks	Facial melanin index decreased 6.1%; facial L* increased 10.3%

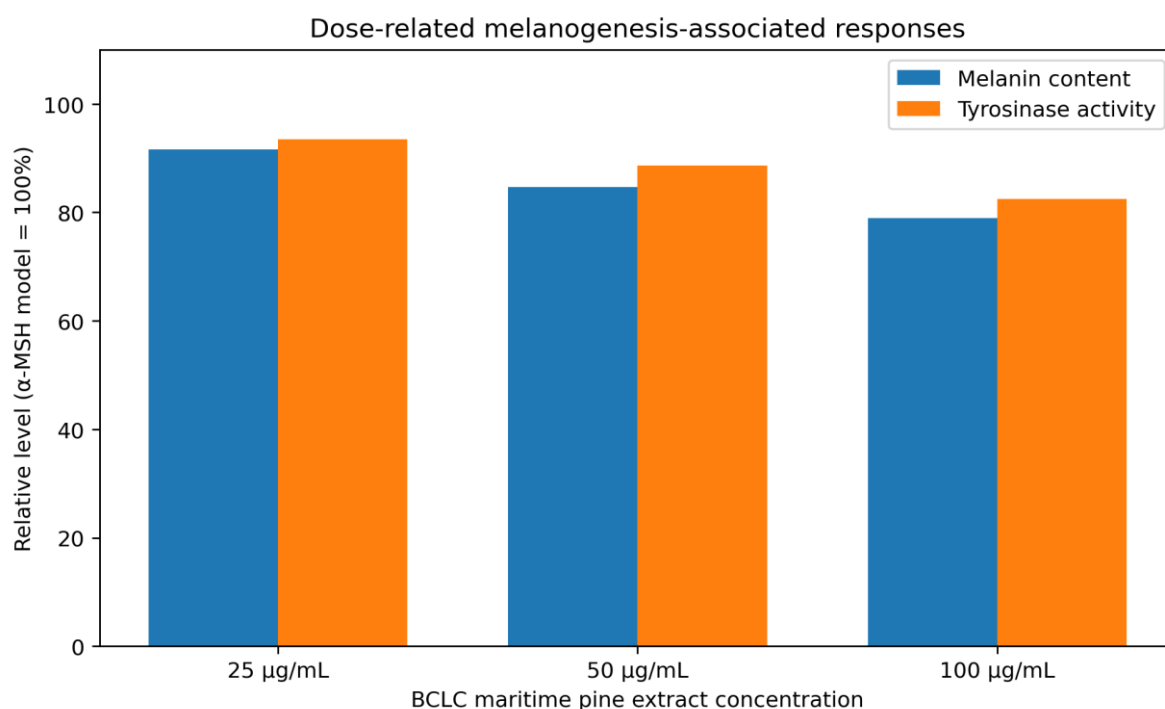


Figure 1. Dose-related melanin and tyrosinase responses in α -MSH-stimulated B16-F10 cells treated with the BCLC oligomer-enriched maritime pine bark extract.

Discussion

The BCLC concentration series produced a graded melanogenesis response without a matching loss of cell viability. At 100 $\mu\text{g/mL}$, melanin was 21.1% below the α -MSH model reference and tyrosinase was 17.5% below it; viability remained $93.8 \pm 2.8\%$. The ordinary extract comparator at the same concentration produced melanin of $90.8 \pm 3.1\%$ and tyrosinase of $92.4 \pm 3.0\%$, whereas the BCLC values were $78.9 \pm 2.6\%$ and $82.5 \pm 2.5\%$.

Two independent cell studies are useful for interpreting that pattern. Leis Ayres et al. reported lower light-induced melanin production, changes in pigmentation-related mediators and inhibition of tyrosinase in cultured human melanocytes exposed to pine bark extract [5]. Kim et al. found anti-tyrosinase and anti-melanogenic effects of Pycnogenol in B16 cells together with antioxidant activity [6]. The BCLC experiment used α -MSH rather than repeated light exposure, so its contribution is the response of a specifically DP2-DP6-enriched preparation under a defined melanogenic stimulus.

The human studies used different clinical situations but share objective color measurements. Zhao et al. assessed seasonal skin darkening during outdoor exposure [7]. Lima et al. measured mMASI and colorimetric contrast in melasma while both groups received the same sunscreen and topical regimen [8]. Fukumura et al. used skin-color measurements for pigmented age spots [9]. Ni et al. had earlier reported changes in melasma area and pigmentary intensity after oral Pycnogenol [10]. Saliou et al. approached light response through MED rather than pigmentation itself [11]. Across these designs, colorimetry, melanin index, L^* , ITA° , pigment contrast and standardized photography are practical choices for a BCLC trial.

The 2026 pilot adds a newer instrument-based example but should be kept separate from single-ingredient evidence. The intervention combined 50 mg Pycnogenol with 187.5 mg pomegranate extract per day for four weeks in ten participants. Facial melanin index decreased 6.1% and facial L^* increased 10.3% at day 28 [14]. Its value here is the measurement approach, not attribution of the result to the BCLC composition.

Formulation control matters before a clinical pigmentation response can be interpreted. Pine-bark extracts contain procyanidins over a wide chain-length range [1], [2], and human pharmacokinetic work identifies both absorbed constituents and metabolites after dosing [12]. The broader ADME literature also shows that procyanidin fate changes with degree of polymerization [13]. A BCLC study can therefore pair its fixed DP2-DP6 specification with circulating metabolites and objective skin-color measurements rather than relying only on a total-proanthocyanidin label claim. Marini et al. provide an additional example of instrument-based skin assessment during oral supplementation [15].

Study Considerations and Future Directions

A randomized BCLC study could prespecify melanin index, CIE L*, ITA°, color contrast and standardized facial imaging over 8-12 weeks. VISIA pigmentation metrics and participant-reported dullness could be collected as secondary outcomes. Phototype, baseline pigmentation, season and visible/UV exposure should be recorded, and plasma phenolic metabolites can be sampled alongside the batch-specific DP2-DP6 profile to examine exposure-response variation.

Conclusion

The DP2-DP6-enriched BCLC microcapsule lowered α -MSH-stimulated melanin and tyrosinase responses in a concentration-related pattern while maintaining high cell viability. At 100 μ g/mL, melanin was 78.9 $\pm$ 2.6% and tyrosinase 82.5 $\pm$ 2.5% of the model. Human maritime-pine studies already use measurable endpoints such as seasonal skin darkening, mMASI, colorimetric contrast and age-spot pigmentation. Those methods can be applied directly in formulation-specific BCLC studies of pigmentation balance and skin-tone uniformity.

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