# Almond Waste for Textile Coloration with Potential Antimicrobial Performance

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Impact on California Agriculture: According to the 2019 California Agriculture Statistics Review, almonds ranked as California's second-largest agricultural product, covering 1,180,000 acres, yielding 1,275,000 tons, and valued at $6.09 billion. In 2020, Corigin reported that California's almond industry generated 857,000 tons of shell waste and 924,000 tons of hull waste. These by-products hold significant potential for repurposing as bio-dyes and bio-mordants for textile dyeing. Recent research highlights the use of nut plant extracts as textile dyes, particularly on wool fabrics. Additionally, almond hull extracts exhibit antimicrobial, antioxidant, antiviral, and mordanting properties due to their polyphenol and tannin content.

Rationale/Introduction: Legislation and environmental pressures drive the advancement of sustainable textile dyeing and finishing technologies. Key focus areas include renewable resources, bio-fibers, biotechnology, and pollution-free, water- and energy-saving processes. Natural dyes from plant and agricultural waste offer a more sustainable alternative to synthetic dyes. The growing need for waste reduction has spurred interest in repurposing agricultural by-products. This project enhances the value of California almond products by minimizing environmental impact and creating sustainable bio-dyes and mordants for textiles. Its success will yield innovative bio-based dyes and mordants with added economic and social benefits.

Experimental Approach: Almond waste from local agricultural firms was processed through cryogenic grinding followed by organic solvent extraction. The concentrated natural colorants were characterized using high-performance liquid chromatography-mass spectrometry (HPLC-MS) and compared to commercial pure standards. A full factorial method was employed to establish the optimal extraction protocol for almond-derived colorants. Various fabric types were dyed using these colorants, with dyeing conditions optimized through orthogonal design and experimentation. Colorimetric data were analyzed alongside assessments of laundry, crocking, and light fastness performance. Additionally, the antimicrobial activity of textiles dyed with almond waste extracts was tested against Gram-negative and Gram-positive bacterial indicators.

Major Conclusion: a. Two colored compounds were identified from the almond waste extracts. The chromatogram of quercetin displayed a larger peak at 370 nm and a smaller peak at 345 nm, with a retention time of 4 minutes. Similarly, the chromatogram of kaempferol exhibited a larger peak at 370 nm and a smaller peak at 345 nm, but with a retention time of 6.5 minutes. b. The optimized extraction conditions were determined to be pH 10, extraction time of 60 minutes, and a temperature of 25°C. c. The preferred dyeing conditions were identified as 60°C, pH 10, and a 70:60 ratio of extraction liquid to water. d. No inhibition zone was observed for the almond hull extracts, whereas the almond shell extracts exhibited a slight antimicrobial effect.

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