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Editorial: Sustainable production of bioactive pigments, volume II

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Editorial on the Research Topic
Sustainable production of bioactive pigments, volume II

Pigments are compounds that humans perceive to have color. In nature, the most abundant natural pigments are chlorophylls, which are the source of green in all plants. Chlorophylls are the primary pigments for photosynthesis to produce energy for the development and growth of plants. Natural plant pigments that contribute to blue, purple, red, yellow and orange in nature are accessory pigments and secondary metabolites that possess diverse structures and functions in plants and offer potential health benefits to humans (Choo, 2019). Anthocyanins, betalains and carotenoids are the common natural plant pigments besides chlorophylls (Choo, 2018). Besides plant pigments, natural pigments can be obtained to a lesser extent from animals [e.g., astaxanthin from shrimp processing waste (Cahú et al., 2012)] or insects [e.g., cochineal colorant or carminic acid from *Dactylopius coccus* Costa (Dactylopiidae, Hemiptera) (Madsen et al., 1993)]. Microalgae and microorganisms are emerging sources of natural pigments (Morales-Oyervides et al., 2020). Bioactive pigments are pigments that interact with or affect cell tissues in the human body. Bioactive pigments that provide health benefits to humans have generated lots of interest among researchers, industries, and consumers. The continual prospecting of terrestrial and aquatic natural resources for bioactive pigments is unsustainable. Therefore, to ensure the continuity of utilization of bioactive pigments for future generations and feasible increases in their usage, sustainable production of bioactive pigments is needed (Choo et al., 2021).

This Research Topic is the second volume of the earlier Research Topic on "*Sustainable production of bioactive pigments*". This Research Topic provides 1 review, 1 mini review and 3 original research articles on the production of pigments, colorants and dyes by microbial and biotechnological means. Joshi et al. summarizes the recent biotechnological innovations in microbial pigment production. Fermentation strategies, co-cultures, and genetic modification of microbial strains (mutagenesis, whole genome shuffling, metabolic engineering, use of CRISPR system) are among the most promising avenues for improvement. Microbial production is not a novel idea from researchers but a reality in many countries worldwide (e.g., astaxanthin, β-carotene, lycopene in Europe).

Filamentous fungi of the *Monascus* genus have been used for centuries in Asia for the production of mainly red pigments and, as such, they remain a subject of ongoing research from various angles. In a mini-review from Buranelo Egea et al., the potential, strategies, and challenges of *Monascus* pigment for food application are summarized. Regulatory aspects are still quite divergent around the world—as with any other product still in the implementation phase—and are mainly related to the (hepatotoxic mycotoxin) citrinin content. All bioactive properties of *Monascus* pigments (over 60 different structures up to now) are also emphasized in this work.

In a research paper, Dias Oliveira et al. demonstrated that maltose production residues can be used to obtain natural pigments by *Monascus ruber* strain CCT 3802 in solid and submerged cultures. Using submerged fermentation, the culture medium containing 10 g L^{-1} of maltose syrup provided the highest concentrations of red pigments (14.54 AU_{510nm} g^{-1} dry biomass) with an intense dark red color. Using by-products, leftovers, food or feed residues is paramount in reducing the costs of microbial pigment production.

Another research paper dealing with *Monascus* focuses on the inhibitory effect of *Monascus purpureus* pigment extracts against fungi and its mechanism of action. In this study by Majhi et al., *Monascus purpureus* pigment extracts were tested (*in vitro*) against *Penicillium expansum* MTCC 4900, *Rhizopus stolinfer* MTCC 10595, and *Aspergillus niger* MTCC 8652 for antifungal activity. Numerous studies mention the antimicrobial properties of microbial pigments. Some cases are clearly established, for pure compounds (e.g., prodigiosin). Others require more experimentation, as they are still based on pigment extracts, whether crude or semi-purified.

As mentioned earlier in this editorial, plants are still playing a big role in the production of pigment, dye and color. Researchers continue investigating new genera and species, discovering new molecules (among the carotenoids, betalains, chlorophylls) and sources (such as wild plants, Amazonian plants, barks from Madagascar). Elgudayem et al. investigated the ultrasonic aqueous extraction of phenolic compounds from *Polygonum equisetifome* roots. The process was optimized using a Box-Behnken experimental design where the factors investigated were the extraction temperature, ultrasonic-assisted extraction time and liquid-solid ratio. The roots of *P. equisetifome* contained high anthocyanin content, water-soluble phenols and condensed tannins. The extracts exhibited promising antioxidant potential and antibacterial activities against several pathogenic bacteria.

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