Production, extraction and characterization of natural fungal pigments from Penicillium sp.

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Natural pigments can be used for different purposes, namely in the textile industry for dyeing cloths, or in the food industry, as colouring agents. Nowadays, some food grade pigments produced by filamentous fungi, namely *Monascus* pigments, Arpink red^{TM} from *Penicillium oxalicum*, riboflavin from *Ashbya gossypii*, as well as lycopene and β-carotene from *Blakeslea trispora* can be found in the market. In the European Union there are approximately 43 colorants authorized as food additives, whereas approximately 30 are approved in the United States, several of them from natural sources. Pigments can also be used in cosmetics, leather or in the pharmaceutical industry. More recently, other applications were found for pigments like in histological staining, in solar cells or as pH indicators. Additionally, important biological properties such as antibacterial, antifungal and herbicidal activities have been reported for natural pigments. There is a growing interest around natural pigments, since their production by living organisms allows reducing the consumption of fossil fuels and environmental pollution compared to synthetic dyes. Furthermore, synthetic dyes can present potential carcinogenic and adverse toxicological effects and their use can become risky for human health. Fungi are reported as potent pigment producers but their practical use is limited by the low extraction yields. In this work, we optimized the production of extracellular pigments by *Penicillium* sp. under submerged fermentation. A mixture of three pigments (yellow, orange and red with λ_{max}=400, 470 and 500 nm, respectively) was obtained under the optimal conditions (23 °C, 150 rpm, 20g/L lactose, 8 g/L supplements, and initial pH=7.0). The pigments were recovered from the fermentation broth using an alternative extraction approach based on Aqueous Two-Phase Systems (ATPSs) composed of two polymers or a polymer and a salt. PEG-salt ATPSs proved to be suitable to separate the pigments (top phase) from other components present in the fermentation broth (bottom phase). Finally, the pigments were characterized regarding their antioxidant and biological activity (antibacterial and antifungal) and potential use as pH indicators (yellow in the acid range and dark red at alkaline pH).