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Current perspective of yellowish-orange pigments from microorganisms- a review

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ABSTRACT

Natural yellowish-orange pigments are derived from bacteria, yeasts, fungi and microalgae, including *Chryseobacterium*, *Monascus* and *Chlorella*. The purpose of this review is to provide an overview of these pigments in various aspects towards exploiting them for numerous functions. These pigments are produced in various shades of yellow-orange and categorised as carotenoids, anthraquinones, zeaxanthin, flexirubin and other compounds. They served as alternative colourants to replace hazardous and toxic synthetic pigments. Researchers are in progress to increase the pigment yield by improving the strains genetically, optimising the fermentation process and utilising cheap agro-industrial waste to reduce the production cost. Yellowish-orange pigments are applied in food, pharmaceuticals, cosmetics and textile industries. This review summarises the current technology status and challenges, economics, biosynthesis of pigment, novel strategies for production of yellowish-orange pigments, biological properties of pigments and metabolic engineering of microorganism with a focus on applications of pigments in food, pharmaceutical, dyeing industries as well as on other applications.

Contents

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1. Introduction

As current inclinations towards health concerns are on rise, non-toxic resources are taken into consideration in various industrial fields. Natural pigments, derived from plants, insects or animals, minerals and microorganisms are biodegradable, renewable, environmental friendly and known for their use in textile dyeing, food ingredients, cosmetics and pharmaceutics (Shahid et al., 2013). Even though synthetic dyes, such as tartrazine, carmoisine used in food industries offer vibrant yellow and red colours, they are notoriously toxic (hepatocellular damage) for human consumption (Amin et al., 2010). Thus, natural pigments serve as potential viable "Green chemistry" to replace synthetic dyes (Yusuf et al., 2011). Among these pigments, carotenoids from plant sources have been extensively studied and reviewed. However, reviews on yellowish-orange pigments produced from microorganisms were still shallow. This review presents comprehensive information about the strains that produce yellowish-orange pigments, biosynthetic pathway of flexirubin production, current technology status and challenges, economics, novel strategies for production of yellowish-orange pigments, biological properties of pigments and metabolic engineering of microorganism with a focus on applications of pigments in food, pharmaceutical, dyeing industries as well as on other applications.

Yellowish-orange pigments occur widely in nature and in general, fruits, vegetables, microorganisms and microalgae are good sources of this pigment. This pigment is responsible for shades of red, orange and yellow of plant leaves, fruits, flowers, birds, insects, fish and crustaceans (Eldahshan and Singab, 2013). Some familiar examples of yellowish-orange compounds are carotenoids, flexirubin, ankaflavin and anthraquinones. In plants, orange of carrot, citrus fruits and saffron, the red of peppers and tomatoes, yellow of corn, mango, turmeric and marigold flowers are due to the presence of carotenoid compounds. In animals, the presence of astaxanthin and canthaxanthin compounds in flamingos, salmon, shrimp and lobsters show pink reddish-orange colourant of the animals (Mezzomo and Ferreira, 2016).

Various microorganisms also produce pigments with colours ranged from red to orange and they are categorised as carotenoids, flexirubin and other compounds. Examples of microorganisms that produce these carotenoids are *Nannochloropsis gaditana* (astaxanthin, β-carotene), *Dietzia natronolimnaea* HS-1 and *Chlorella zofingiensis* (canthaxanthin), *Rhodoturula glutinis* (β-carotene), *Monascus* sp. (ankaflavin, monascorubramin), *Ashbya gossypi* (riboflavin), and *Penicillium oxalicum* (anthraquinone) (Cardoso et al., 2017). Besides microorganisms, microalgaes, namely *Chlamydomonas reinhardtii* and *Chlorella zofingiensis* produce natural yellowish-orange pigments such as α-carotene, lutein, zeaxanthin, anteraxanthin, neoxanthin and violaxanthin (Mulders, 2014).

Although some natural yellowish-orange pigments are already available, pigments from microorganism play a vital role for this pigment production due to its advantage over plants in terms of availability, stability and easy down streaming process (Tuli et al., 2014). Pigment production is also cheaper and higher yields could be obtained through strain improvement. Pigments also possess various pharmacological activities such as antioxidant, anticancer and antimicrobial activities. In line with that, natural pigments serve as alternative colouring agents are in demand in industries such as textile, plastic, paint, paper and printing (Tuli et al., 2014).

2. Methodology

While researchers such as Dufossé et al. (2014) and Venil et al. (2014a, 2013) have identified the sustainability benefits of microorganism pigments and their advancements in fermentation in general, it is important to focus on particular pigment, yellowish-orange pigment and examine its potential benefits and applications. This paper investigates the current challenges, economics, novel strategies and application of yellowish-orange pigment from microorganisms through exploratory reports and studies on this pigment.

The information was identified through reports and reviews for yellowish-orange pigment for various microorganisms. Most of the reports were based on yellow pigments from fungus, including *Monascus* sp. and yeast. Although various reviews were found for carotenoids, zeaxanthin and ankaflavin, least studies were carried out for flexirubin-type pigments.

A list of microorganisms producing yellowish-orange pigment, the source of strain isolation and country was adopted from various resources and listed in Table 1. The compounds present in yellowish-orange pigment and the biosynthesis of flexirubin were discussed in Section 3 and 4. The strategies for strain improvement and fermentation for high pigment production were summarised in Section 5 and 6. Processing techniques, pilot scale production and pharmacological activities of pigment were discussed in Section 7, 8 and 9, respectively. Market potential and the pigment applications in various fields were described in Section 10 and 11. An overall summary and future perspectives of the yellowish-orange pigment were provided at the end of Section 12.

3. Yellowish-orange pigments producing microorganisms

Natural yellowish-orange pigments are produced by diverse genera of microorganisms, including bacteria, yeasts, filamentous fungi (Berman et al., 2015) and microalgae (Henríquez et al., 2016). These yellow pigments producers are varied phylogenetically and the production depends on the location of isolated microorganisms. As shown in Table 1, these include quite a selection of environs as these microorganisms have been found associated with the soil and water.

Most recently, there have been different strategies for studying yellow pigment producers in different parts of the world. Venil et al. (2014b) isolated and identified *Chryseobacterium artocarpi* CECT 8497 from rhizosphere soil of *Artocarpus integer*. The bacteria produce yellowish-orange pigment which belongs to flexirubin type. The16S rRNA gene sequences and DNA-DNA hybridization test demonstrated that this strain constituted a distinct phyletic