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Effect of carrier agents on the physical properties and morphology of spray-dried *Monascus* pigment powder

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ABSTRACT

Spray drying is an economic technique used in preservation and production of *Monascus* pigment powder. This study was performed to encapsulate the *Monascus* pigment with maltodextrin using spray drying technique with three types of carrier agents: propylene glycol, mannitol and polyglycerol ester at different concentrations (0.5%, 1% and 1.5%). Analyses of particle size, the spattering behavior, microstructure, color value, and thermal profile were performed on the obtained powder. The addition of propanediol, mannitol and polyglycerol ester in combination with maltodextrin led to an increase of 17.5%, 45.8%, and 23.5% in the volume mean diameter of *Monascus* pigment powder, respectively. The decrease of spattering of *Monascus* pigment with maltodextrin was clearly evident in the case of formulations containing 1.5% polyglycerol ester. Scanning electronic microscopy analyses showed that *Monascus* pigment particle treated with maltodextrin exhibited microstructures that were smooth and dented, while the particles treated with carriers exhibited rough, irregular surface and adherence of smaller particles on their surfaces. UV–visible spectroscopy proved that the addition of carriers did not influence the molecular structure of *Monascus* pigment compared to the powder without carrier treatment. Differential scanning calorimeter analysis revealed that mannitol enhanced water vaporization during spray drying process as lower enthalpy change was observed in thermogram. The addition of an appropriate carrier (0.5%, 1.5% propanediol or 1% mannitol) improved the color values of *Monascus* pigment.

1. Introduction

Monascus red pigment is a product resulting from rice fermentation using *Monascus* sp, and it is commonly called Monascorubramin and Rubropuntamine (Mapari et al., 2005). It has been utilized extensively as a natural food colorant such as in the making of sausages, Chinese cheese, and red wine for many years in Asia. *Monascus* pigments are also recognized as one of the potential food colorants in the United States and European Union (Kim & Ku, 2018).

The research of *Monascus* pigment was mainly focused on its preparation, isolation, and functional properties (Feng, Shao, & Chen, 2012). It was reported that *Monascus* pigment production was enhanced by the use of lactose as a carbon source, extractive fermentation, and intraspecific protoplast fusion (Costa & Vendruscolo, 2017; Lv, Zhang, Liu, Zhang, & Cheng, 2017; Wang, Zhang, Wu, & Wang, 2015). The functional properties of *Monascus* pigment were mainly about the antioxidant activity, pharmaceutical and clinical properties that can counteract common diseases, including obesity, type-2 diabetes, and cancer (Daehwan & Seockmo, 2018; Teixeira, Teixeira, & Freitas, 2011).

Monascus pigments are commonly produced in powder form in industry. The main advantage of the powder form over liquid form is the improvement of shelf-life through reduction of the water content. The physicochemical and functional properties of the pigment powders can be preserved until they are required (Priatni, 2015). The behavior of food powder ingredients during storage, processing and utilization depends on their physical and flow properties. For the purpose of making the pigment powder as a functional ingredient, it was aimed to study the encapsulation techniques of *Monascus* red pigment.

Spray drying is defined as a technology of protecting materials in matrices that can help to increase the shelf life, protect the biological properties and release their components at controlled rates under

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specific conditions (Huang et al., 2017; Shishir & Chen, 2017). Spray-dried pigment has great economic potential. However, pigment powders obtained by spray drying have some problems in their properties, such as spattering, floating, stickiness, low solubility and high hygroscopicity, which make the packaging and handling of the powder become difficult. Literature shows that physical properties of the powdered product, i.e. moisture content, bulk density and particle size are significantly affected by the drying temperature and carrier agent (Igual, Ramires, Mosquera, & Martínez-Navarrete, 2014; Janiszewska-Turak, 2017; Lao & Giusti, 2017). Moreno (2016) reported that different natural carriers such as maltodextrin, whey protein, and pea protein can be used to formulate a polyphenol-enriched grape marc extract by spray drying. Carrier agents such as maltodextrin with various DE levels, gum Arabic, waxy starch and soybean isolates have been demonstrated in different studies to increase the retention of pigments during spray drying process, due to their capability to change the hygroscopicity and thermoplastic characteristic of the powders (Fazaeli, Emam-djomeh, Ashtari, & Omid, 2012; Ferrari, Germer, Alvim, Vissotto, & de Aguirre, 2012; Yousefi, Emam-Djomeh, & Mousavi, 2011). It is possible that the addition of carriers during spray drying could reduce the spattering phenomena, considering the fact that carriers could adsorb at the interface of particles.

In order to enhance the characteristics of spray-dried *Monascus* pigment powder by reducing the spattering and improving color value, this work aimed to prepare *Monascus* pigment using a carrier maltodextrin and the addition of other carriers (propanediol, mannitol and polyglycerol ester) during the spray drying process. Other physical properties such as particle size distribution, microstructure, and thermal behavior were also determined to understand the effect of carrier agents on the spray-dried *Monascus* pigment powder.

2. Materials and methods

2.1. Materials

The *Monascus* red pigment and maltodextrin with average dextrose equivalent of 18 were supplied by Guangdong Tianyi Biological Technology Co. (Guangdong, China). The molecular formula of *Monascus* red pigments was shown in Fig. 1 (Watanabe et al., 1999). Propanediol (CAS#57-55-6) was purchased from Shanghai Source Biotechnology Co., Ltd (Shanghai, China). Mannitol was purchased from Hebei Baiwei Biological Technology Co., Ltd (Hebei, China). Polyglycerol ester was purchased from Shandong Knost Biological Technology Co. Ltd (Shandong, China). All other chemicals were of analytical grade.

2.2. Preparation of Monascus pigment solution

Carrier agent solutions were prepared by mixing different amounts of the maltodextrin (14%, 13.5%, 13%, and 12.5%) with propanediol, mannitol and polyglycerol ester (0, 0.5%, 1% and 1.5% in the final solution) in deionized water, respectively, and were kept under magnetic stirring until complete dissolution. The mixture of *Monascus* pigment (26%) and the carrier agents (14%, maltodextrin + propanediol/mannitol/polyglycerol ester) was kept under magnetic stirring until complete dissolution. *Monascus* pigment powder treated with maltodextrin without other carrier agents is the control powder.

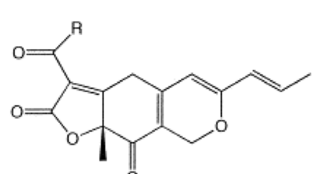

Fig. 1. Molecular formula of *Monascus* red pigments. R = C_5H_{11}-Rubropunctatin, C_7H_{15}-Monascorubrin.

2.3. Spray drying of Monascus pigment powder

Mini spray dryer (H-2000, Mobile Minor TM Niro, America) was used to produce the spray-dried *Monascus* pigment powder. The inlet air temperature was set at 250 °C, while, the outlet air temperature was about 90-100 °C. The outlet temperature is the result of the heat and mass balance in the drying chamber and therefore cannot be regulated. The liquid feed to the dryer was controlled by the pump rotation speed at about 12 mL/s. The flow of the drying air was about 8 m^3 min^{-1}. The experiments were performed at constant process conditions. The powder obtained was placed into aluminium laminated polyethylene bags (approximately 350 g), which was stored at 25 °C for further analysis.

2.4. Laser diffraction particle size analysis

The particle size distribution of *Monascus* pigment particles was measured using Bettersize laser 2001 particle size analyzer (BT-2001, Dandong Bettersize Instruments Ltd., Liaoning, China). Samples (1 g) were placed in the particle size tester. The refractive index was set as 1.52. The compressed air was used as dispersion medium. The Laser analyzer uses dynamic light scattering (DLS). Stokes-Einstein equation was used to calculate the particle size and distribution. The results were reported as particle size distribution with average particle size expressed in μm.

2.5. Powder spattering characteristics

The dispersity of *Monascus* pigment was used to characterize the spattering of the powder. In this study, the intelligent powder physical property tester (BT-1001, Baite Instruments, Dandong, China) was employed to measure the spattering of *Monascus* pigment. The test feeding was set at 4-speed (the amplitude was around 0.57 mm) and the feeding time was 200 s. According to the mechanism of the intelligent powder physical property tester, the smaller dispersity means the less spattering.

2.6. Scanning electronic microscopy (SEM)

The morphology of the *Monascus* pigment powders was observed using a Jeol JSM-T200 scanning electronic microscopy (Jeol, Tokyo, Japan). The samples were atomized on a small barrel and were covered with a fine layer of gold (15 mm) through sputter coating attachment of balzers, in vacuumed evaporators. For observation, SEM was set with a voltage of 10 kV. The microphotographs were carried out with a camera coupled to the microscopic. The samples were observed with magnifications of 1000 × and 3000 × (Carvalho et al., 2016).

2.7. UV–visible spectroscopy

Monascus pigment (1 g) was solubilized into 100 mL of distilled water and then diluted to 300 times with distilled water (Jian, Sun, & Wu, 2017). The path length of the quartz cell used in this experiment was 1 cm. The absorbance spectrum of *Monascus* pigment was recorded by a Shimadzu UVmini-1240UV–vis spectrophotometer (Shimadzu, Co., Ltd., Tokyo, Japan) from 200 to 700 nm.

2.8. Color values

Monascus pigment (1 g) was solubilized into 100 mL of distilled water. The obtained solution was then diluted to 300 times with distilled water (Jian et al., 2017). The color values of *Monascus* pigment was determined spectrophotometrically by measuring the absorbance at 490 nm using a Shimadzu UVmini-1240UV–vis spectrophotometer.