LWT - Food Science and Technology 207 (2024) 116663

Contents lists available at ScienceDirect

LWT

journal homepage: www.elsevier.com/locate/lwt

Encapsulation of resveratrol in alginate microcapsules using internal gelation technique: Fabrication, characterization and release kinetics

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ARTICLE INFO

Keywords:
Resveratrol
Spray drying
Freeze drying
Thermal stability
Light stability
In vitro release

ABSTRACT

Resveratrol (RES) is a proven anticancer, antioxidant, anti-inflammatory, and cardioprotective compound. However, low bioavailability, poor water solubility, and sensitivity to UV light and heat limit RES's use in food applications. In this study, we aim to protect RES by encapsulating it in sodium alginate (NaAlg) matrix using internal gelation, followed by drying the moist microencapsulates using spray and freeze-drying techniques. The spray-dried microencapsulates exhibited a smaller mean diameter (5.57 ± 2.40 μm), higher encapsulation efficiency (91.32 ± 1.98%), and higher ζ-potential (−61.9 ± 2.33 mV) compared to freeze-dried microencapsulates. SEM images revealed the smooth and spherical surface of the spray-dried microencapsulates, while the freeze-dried samples exhibited irregular shapes and porous textures. FTIR results showed polyelectrolyte interactions between NaAlg, RES, and $CaCO_3$. XRD and DSC results confirmed the incorporation of RES in the NaAlg matrix. Spray-dried microencapsulates demonstrate the highest RES retention of 80.89 ± 0.70% and 78.59 ± 0.27% after 4 h of UV light and thermal treatments, respectively. *In vitro* release studies showed that spray-dried microencapsulates demonstrate a delayed gastric release compared to freeze-dried microencapsulates. The release mechanism of RES from the microencapsulates was effectively described by the Shalin-Peppas model.

1. Introduction

Resveratrol (RES) is a naturally occurring bioactive compound that has recently attracted a lot of attention as a food nutraceutical owing to its numerous health benefits. It is commonly found in various plant sources, including grapes, peanuts, and berries (Walle et al., 2004). RES belongs to the stilbene family of polyphenols, in which the phenyl groups are replaced by hydroxy groups at positions 3, 5, and 4. The hydroxyl groups (-OH) attached to the phenol rings make RES a highly reactive molecule with high antioxidant properties (Salehi et al., 2018; Zhang et al., 2021). It has two geometric isomers, *cis* and *trans*, with *trans* being more prevalent and having various biological activities associated with it. Numerous *in vivo* and *in vitro* studies have reported that RES is effective in the treatment of cancer, diabetes, neurodegeneration, cardiovascular diseases, inflammation, and other age-related macular degenerations (Aluyen et al., 2012; Bradamante et al., 2004; Gambini et al., 2015). However, the low water solubility, high chemical instability, and poor oral bioavailability of the RES limit its application as a nutraceutical in the food sector. In humans, oral absorption of RES is approximately 75% and occurs primarily through transepithelial diffusion. Because of extensive metabolism in the liver and intestines, RES has an oral bioavailability of less than 1% (Walle, 2011). Furthermore, *trans*-resveratrol was highly photosensitive and vulnerable to heat processing (Khan et al., 2019; Sessa et al., 2011; Sharkawy et al., 2020). The elevated temperatures commonly utilized in food processing procedures can lead to the deterioration of RES, thereby diminishing its bioavailability. When exposed to UV irradiation, *trans*-resveratrol can undergo photoisomerization, converting into its *cis*-form (Trela & Waterhouse, 1996), which generally offers fewer health benefits than its *trans* counterpart (Orallo, 2019). Considering this, encapsulation emerges as a promising strategy to protect RES against adverse conditions and improve its chemical stability, water dispersibility, and bioavailability (Davidov-Pardo & McClements, 2014; Marcillo-Parra et al., 2021). Encapsulation is the process of entrapping active

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https://doi.org/10.1016/j.lwt.2024.116663
Received 16 May 2024; Received in revised form 6 August 2024; Accepted 19 August 2024
Available online 21 August 2024