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RESEARCH

# Spray-Dried Microencapsulation of Roselle Calyx Extract: Investigating the Impact of Maltodextrin and its Combination with Alginate and Carboxymethyl Cellulose as Wall Materials

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## Abstract

Roselle (*Hibiscus sabdariffa* L.) anthocyanins serve as both colorants and bioactive compounds but are highly unstable to pH, light, heat, metal ions, oxygen, and enzymes. Microencapsulation using appropriate techniques and matrix materials enhances the stability of anthocyanins. This study aimed to compare the physicochemical properties and antioxidant activity of spray-dried microencapsulated roselle anthocyanins using a single matrix (maltodextrin) and binary matrix combinations. The binary matrices included maltodextrin-alginate at ratios of 49:1, 47:3, and 46:4, and maltodextrin-carboxymethyl cellulose at ratios of 49.5:0.5, 49:1, and 48:2. The use of a binary matrix improved the physicochemical properties of the microcapsules. The selected matrices, maltodextrin-alginate (49:1) and maltodextrin-carboxymethyl cellulose (49:1), produced microcapsules with the following characteristics, a yield of 52.80% and 50.67%, a pink-colored powder with a non-sticky texture, moisture content of 2.95% and 3.87%, encapsulation efficiency of 98.01% and 98.80%, an average particle size of 1.406 µm and 1.365 µm with a homogeneous distribution (PDI < 0.7), and the capacity to retain red color stability at pH 2.6–5. The microcapsules exhibited an amorphous structure characterized by a non-spherical and agglomerated form. ATR-FTIR analysis confirmed that the anthocyanins were successfully trapped within the matrix through visible changes in the spectra. The microcapsules demonstrated free radical scavenging activity against DPPH, with $IC_{50}$ values of 3.8087 and 3.0438 mg/mL. The addition of alginate or carboxymethyl cellulose to maltodextrin as a matrix not only resulted in powder with improved physicochemical properties but also enhanced encapsulation efficiency, suggesting their potential for stabilizing anthocyanins in functional food applications. Therefore, further research is needed to explore other binary matrix combinations, optimize the release behavior of anthocyanins, and evaluate their performance in real food or pharmaceutical applications.

**Keywords** Anthocyanin protection · Binary encapsulation system · Natural colorant · Polysaccharide-based carriers · Spray-drying microencapsulation

## Introduction

Color is a crucial parameter influencing consumer acceptance of a product [1]. With increasing awareness of the health and environmental concerns associated with synthetic dyes, there is a growing demand for natural colorants derived from various sources, including plants, minerals, and microorganisms. Among these, anthocyanins are widely recognized for their ability to provide vibrant blue, red, and purple hues, depending on pH [2, 3]. In addition to their coloring properties, anthocyanins offer antioxidant benefits, making them valuable for food and pharmaceutical applications [4, 5]. However, their instability to environmental

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