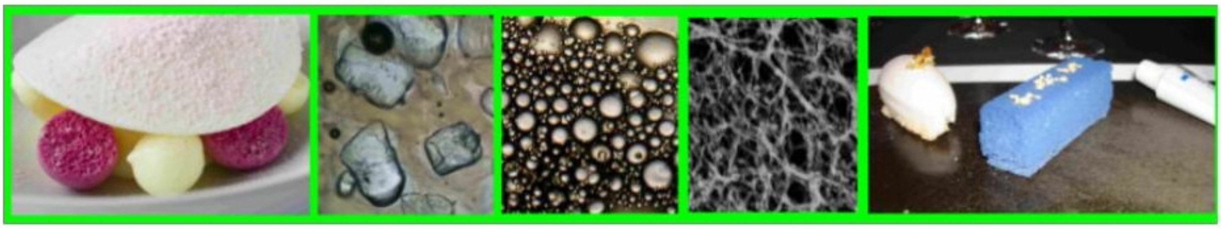

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Image for thought

A double emulsion with leaf extract

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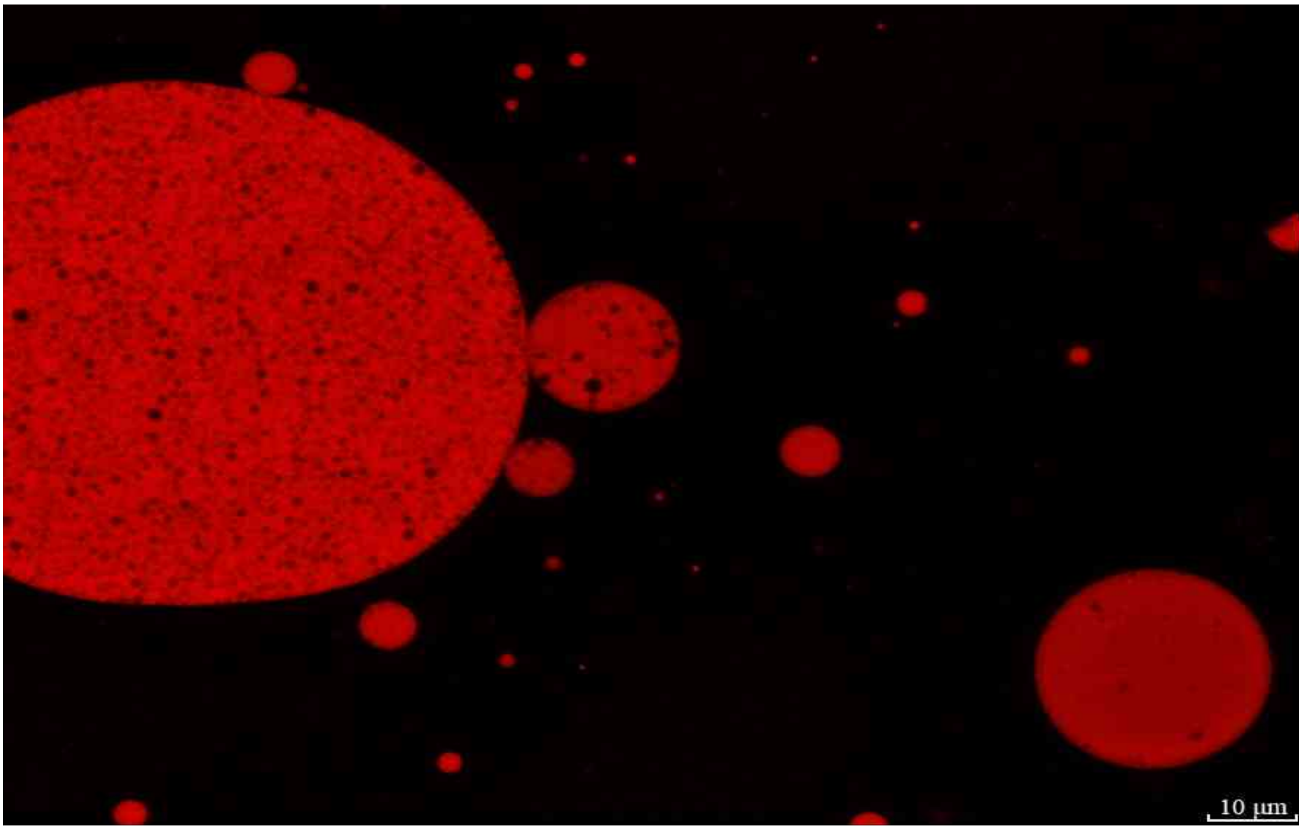

*Figure 1. Photomicrograph of a double emulsion encapsulating "Pitanga" (*Eugenia uniflora *L.) leaf hydroethanolic extract obtained by a fluorescence microscope (BX51, Olympus, Tokyo, Japan).*

Image for thought

Abstract

The polydispersity of a water-in-oil-in-water (W/O/W) double emulsion is discussed from a photomicrograph picture captured by fluorescence microscopy with Nile Red dye to color the oil phase of the W/O/W emulsion. Large drops of soybean oil are dispersed in the external aqueous phase, with small droplets of water containing Pitanga (*Eugenia uniflora* L.) leaf hydroethanolic extract inside. W/O/W emulsions have great relevance in several industries, including food, due to their ability to encapsulate aqueous and polar bioactive compounds, promoting controlled release and protection of bioactive properties, and ability to create multi-layered flavors and textures. However, the stability and formation of monodisperse W/O/W emulsions still represent significant challenges, especially due to droplet size polydispersity, which affects the stability and functionality of the system.

Keywords
emulsion, double emulsion, picture

The photomicrograph of a water-in-oil-in-water (W/O/W) double emulsion (Figure 1) was obtained using Nile red dye (0.25 mg/mL DMSO) added in the double emulsion at 1:10 ratio (dye:sample, *v/v)* to coloring the oil phase (Tessaro *et al.,* 2022). The sample was placed on a microscope slide and the photomicrograph was captured using a fluorescence microscope (BX51, Olympus, Tokyo, Japan) with a 100 x oil immersion objective lens (Tessaro *et al.*, 2022). Large droplets of soybean oil (red) dispersed in an external aqueous phase and containing small droplets of water (black) inside containing "Pitanga" leaf hydroethanolic extract (*Eugenia uniflora* L.) can be observed in this Figure.

Double emulsions are a type of colloidal system where a primary emulsion is dispersed within a secondary one, forming a complex structure with three distinct phases (Dickinson, 2011). The most studied type is the water-in-oil-in-water ($W_1/O/W_2$) emulsion, where an inner water-in-oil emulsion (W_1/O) is dispersed in an outer aqueous phase (W_2).

These emulsions are valuable across industries like food, cosmetics, and pharmaceuticals due to their ability to encapsulate both hydrophilic and hydrophobic compounds, offering versatile properties for controlled release and enhanced product sensory characteristics. The lipidic and external aqueous phases protect the encapsulated bioactive compounds, preserving their stability and functionality in different applications (Heidari *et al.,* 2022).

$W_1/O/W_2$ emulsions are interesting in gastronomy for creating unique textures, controlling flavor release, protecting sensitive ingredients, increasing bioaccessibility (Tessaro *et al.,* 2024), and producing foods low in fat, salt, or sugar (Buyukkestelli and El, 2021). They encapsulate both hydrophobic and hydrophilic compounds, offering a creamy, smooth consistency while preserving the nutritional properties of ingredients like essential oils, probiotics, vitamins, and antioxidants (Øye *et al.*, 2023).

$W_1/O/W_2$ emulsions also provide an alternative for extending shelf life and adding functional benefits to foods, meeting consumer demands (Øye *et al.,* 2023). With their ability to create multi-layered flavors and textures, $W_1/O/W_2$ emulsions are an alternative tool in the developing of healthier and functional dishes, such as sauces, yogurts, ice cream, and beverages (Zhang *et al.,* 2024). For example, a low-fat meat batter was produced with a $W_1/O/W_2$ emulsion encapsulating *Murraya koenigii* berries extract and showed better oxidative stability, without affecting the other attributes of the food product (Kumar and Kumar, 2020).

Despite their potential, the formation and stabilization of $W_1/O/W_2$ emulsions present challenges. Achieving high kinetic stability requires careful selection of emulsifiers and emulsification methods (McClements, 2004). Emulsifiers, which reduce interfacial tension between aqueous and lipidic phases, are key to stabilizing the emulsion and preventing droplet coalescence. Mechanical energy during emulsification is crucial for reducing droplet size and ensuring uniform distribution. The size and polydispersity of droplets—the variation in their size distribution—are significant factors influencing the emulsion's stability and functionality (McClements, 2004).

Polydispersity in $W_1/O/W_2$ emulsions, where droplet sizes vary widely, can negatively affect the system's properties, such as stability, texture, and functionality. Large droplets may lead to coalescence, where droplets merge, and Ostwald ripening, where smaller droplets dissolve into larger ones due to pressure differences, potentially causing the breakdown of the emulsion (Dickinson, 2011). These destabilizing processes limit the practical applications of $W_1/O/W_2$ emulsions, particularly in food and cosmetics, where consistent texture and visual stability are critical (McClements, 2004). For example, polydisperse emulsions may appear grainy or have uneven texture, which detracts from the sensory appeal of products (Chen *et al.*, 2022). High polydispersity also leads to phase separation over time, as larger droplets settle more quickly than smaller ones (McClements, 2004).

The formation of monodisperse double emulsions—where droplet sizes are uniform—remains a major challenge. Various strategies, such as optimizing the selection of emulsifiers, emulsification techniques, and processing conditions, are employed to minimize polydispersity and enhance emulsion stability and performance. These include adjusting factors like viscosity, phase ratios, temperature, pH, and ionic strength, all of which affect droplet formation and stability (McClements and Jafari, 2018).

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