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Complexation between Whey Protein and Octenyl Succinic Anhydride Modified Starch: A Novel Approach for Encapsulation of Lipophilic Bioactive Compounds

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Abstract

Proteins and polysaccharides are frequently used in food industry, and their interactions in food systems could affect the properties of food products such as the texture and stability. Therefore, the knowledge of the interactions between these two macromolecules is of great significance for food manufacturers.

The aim of this study was to investigate the complexation process between whey protein isolate (WPI) and octenyl succinic anhydride (OSA)-modified starch and explore the application of their interactions in the encapsulation of lipophilic bioactive compounds.

The formation of complexes between WPI and OSA-modified starch was investigated as a function of pH (7-3), the heat treatment of WPI, and the concentration ratio of WPI and OSA-modified starch (1:1, 1:10 and 1:20). The complexation process was evaluated by the determinations of the absorbance, particle size and ζ-potential of the mixtures, which were determined by spectrophotometer and dynamic light scattering. It was found that the OSA-modified starch was more likely to interact with heated WPI (HWPI, 90°C for 20 min) rather than non-heated WPI (NWPI). The optimum condition for the formation of insoluble coacervates was at ratio of 1:10 and pH 4.5, which was driven by both electrostatic and hydrophobic interactions. The structure of the complexes formed under the optimum condition could be affected by different molecular characteristics of OSA-modified starch including molecular weight (Mw) and degrees of substitution (DS) value. It was found that OSA-modified starch with higher Mw was difficult to form a dense precipitation phase with HWPI due to its higher viscosity restricting the movement of any particles present. Stable soluble complexes could be formed between HWPI and OSA-modified starch with higher DS value under the same condition, which may be attributed

to the stronger steric hindrance of OSA-modified starch with higher DS values. It seems that the complexation between HWPI and OSA-modified starch was induced by electrostatic interactions, while the structural properties of the complexes were determined by hydrophobic interactions.

The soluble complexes between HWPI and OSA-modified starch with a DS value of 4.29 ± 0.11% formed at ratio of 1:10 and pH 4.5 were applied to encapsulate β-carotene, which was used as a model of lipophilic bioactive compounds in this study. The apparent aqueous solubility of β-carotene was enormously improved (264.05±72.53 μg/g) after encapsulation in the soluble complexes. No significant differences were observed under transmission electron microscopy (TEM) and scanning electron microscope (SEM) between the soluble complexes before and after encapsulation of β-carotene whether in a liquid or a powdered form. Results of Fourier transform infrared spectroscopy (FT-IR), X-ray diffraction (XRD) and differential scanning calorimetry (DSC) indicated that the β-carotene was in an amorphous form loaded inside the soluble complexes, which suggested that the molecules of β-carotene evenly distribute within the complex particles by hydrophobic force. In addition, the β-carotene-loaded freeze-dried soluble complexes showed good redispersion behaviour and a high retention rate of the loaded β-carotene (89.75%), which indicated that the β-carotene-loaded soluble complexes could be successfully converted into a powdered form. The accelerated stability study showed that these soluble complexes could effectively protect the loaded β-carotene at pH 4.5 during storage, especially after 7 days of storage. This indicated the potential of using the soluble complexes between HWPI and OSA-modified starch to protect lipophilic bioactive compounds for long-term storage under low pH conditions.

This study may be beneficial for the potential using the soluble complexes between HWPI and OSA-modified starch as delivery systems for lipophilic bioactive compounds in commercial applications.

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ASSP: acid soluble soy protein

CMC: carboxymethylcellulose

DE: degrees of esterification

DMSO: dimethyl sulfoxide

DS: degrees of substitution

DSC: differential scanning calorimetry

FT-IR: Fourier transform infrared spectroscopy

HWPI: heated WPI

Mw: molecular weight

NWPI: non-heated WPI

OSA: octenyl succinic anhydride

pI: Isoelectric point

SC: soluble complexes

SEM: scanning electron microscope

SSPS: soy soluble polysaccharide

TCNN: *trans*-cinnamaldehyde

TEM: transmission electron microscopy

WPC: whey protein concentrate

WPI: whey protein isolate

v/v: volume/volume

w/v: weight/volume

w/w: weight/weight

XRD: X-ray diffraction