Adsorptive precipitation of vitamins D_3 and E on gum arabic and alginate dried using Pressurized Gas eXpanded liquid (PGX) process

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Functional food products are formulated with added bioactive ingredients that provide health benefits beyond basic nutrition function. However, their manufacture has different challenges when adding hydrophobic bioactives, such as vitamins D_3 ($VitD_3$) and E (VitE), into aqueous-based formulations. Moreover, these vitamins are sensitive to heat and can be degraded or oxidized in the presence of free radicals, light and oxygen, and $VitD_3$ has a crystalline nature. To overcome these limitations, the objective of this study was to use water-soluble polysaccharides dried using the Pressurized-Gas eXpanded liquid (PGX) process as a delivery system after adsorptive precipitation of $VitD_3$ and VitE with supercritical CO_2 (SC-CO_2). PGX-processed polysaccharides with unique morphologies of micro/nano-sized particles and high surface area show great potential as delivery systems for such hydrophobic bioactives.

To determine the effects of processing parameters on the adsorptive precipitation of $VitD_3$ and VitE on PGX-dried gum arabic (GA) and sodium alginate (SA), the loading content of vitamin, crystallinity, and morphology were determined at different recirculation times (30, 45 and 60 min) and recirculation flow rates (135, 190 and 250 mL/min) of SC-CO_2 at 300 bar and 50 ^{o}C in triplicate, using a fast depressurization rate of 130-150 bar/min. Release kinetics, thermal behavior and storage stability of the vitamin-loaded powders were also evaluated.

The higher loading of $VitD_3$ on the biopolymers was achieved at the recirculation flow rate of 190 mL/min as 10.1 ± 0.2% (w/w) for GA and 250 mL/min as 13.7 ± 0.1% (w/w) for SA at 45 min of recirculation time. Uniform coating of $VitD_3$ on the surface of biopolymers was demonstrated by helium ion microscopy (HiM). $VitD_3$ retained some crystalline form on the loaded gum arabic (L_D-GA). Over 60 days of refrigerated storage, after an initial decrease, the loading of samples stabilized after 21 days for loaded sodium alginate (L_D-SA) at 82% and after 28 days for L_D-GA at 80% of the original $VitD_3$ levels. Sustained release of $VitD_3$ was demonstrated for L_D-GA sample in the simulated intestinal fluid, reaching 18.6% of the initial amount at the end of 240 min digestion, compared to 3.6% for L_D-SA and 1% for pure $VitD_3$.

For VitE, the highest loading was achieved at the same processing conditions (135 mL/min and 45 min) for both biopolymers with maximum values of 14.95 ± 0.2% (w/w) for GA, and 22.35 ± 0.1% (w/w) for SA. Homogeneous coating of VitE on the biopolymers' surface was displayed by HIM images. Loaded samples were quite stable over refrigerated storage for 28 days with a drop of VitE loading to 91% for L_E-GA and 96% for L_E-SA of the initial loading. Adsorption kinetics results showed a difference in the rate of the concentration increase up to 50 min for both biopolymers, indicating differences in the surface areas of the biopolymers as well as the interactions between VitE and biopolymers. In the simulated intestinal fluid, sustained release of VitE from L_E-GA over 240 min digestion time reached 20.1% of the initial amount, compared to 4% for L_E-SA and < 1% for pure VitE.

The findings on adsorptive precipitation of $VitD_3$ and VitE on the PGX-processed gum arabic and sodium alginate powders demonstrated the great potential of this technology and these food biopolymers for use as delivery systems of fat-soluble vitamins, targeting subsequent aqueous-based product applications.