Characterizing the rheological properties of cellulose nanocrystals in the stomach using a dynamic in vitro model

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Previous studies indicated that cellulose nanocrystals (CNC) can form hydrogel networks during gastric digestion, resulting in an increased digesta viscosity. This property could contribute to delayed gastric emptying and increased satiety feeling which is beneficial to disease management such as obesity and diabetes. The objective of this study was to investigate the influence of pH levels and ionic strengths present in the gastric environment, and dynamic gastric conditions on the rheological properties of cellulose nanocrystal (CNC). Sodium alginate (SA) and pectin (PE), which are widely studied for their gel formation properties in the stomach, were studied as a comparison.

CNC suspension at 4%, 6%, and 8% (w/w) concentrations, and sodium alginate and pectin solutions at 2%, were prepared with deionized water. The effect of pH was studied by adjusting the pH of the samples to 1.5, 2.5, 3, and 5, respectively, followed by viscosity measurement. The effect of ionic strength was studied by adding a series of concentrations of CaCl2 and MgCl2 solutions to the samples and analyzing the changes in the rheological properties. A dynamic gastric simulator model (DGSM) was used to test the behavior of the CNC, SA and PE samples during gastric digestion. The rate of gastric emptying was recorded during the 2 h simulated digestion.

CNC formed strong hydrogel at low pH (1.5) and high concentration (8%). Both CaCl2 and MgCl2 addition enhanced the formation of CNC hydrogel, while Mg^{2+} is more effective than Ca^{2+}. SA developed a viscous gel with the addition of salt addition, and Ca^{2+} led to a thicker and more potent gel network. In contrast, no significant effect of ionic strength on pectin gelation was observed. During dynamic gastric digestion, SA formed a strong gel network in the stomach delaying gastric emptying. CNC formed hydrogel to a different extent depending on the concentration while not significantly affecting gastric emptying. No gel formation was observed for PE.

This study provided useful information on the behavior of CNC and other polysaccharides during gastric digestion, which could promote the potential application of CNC in functional foods aiming to delay gastric emptying and reduce calorie intake.