In vitro gastrointestinal digestibility of native, hydroxypropylated and cross-linked wheat starches

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The digestibility and estimated glycemic indices (GI) of native (NWS), cross-linked (CLWS) and hydroxypropylated wheat starches (HPWS) were obtained by in vitro enzymatic hydrolysis. The resistant starch (RS) content and GI were found to be 6.59 and 93.13 for NWS, 7.57 and 92.20 for CLWS, and 13.15 and 89.04 for HPWS, respectively. The amounts of glucose release for CLWS were approximately 6–11%, and for HPWS were 16–19%, lower than that for NWS after digestion under simulated intestinal conditions (SIC). The linear and two-term exponential models were fitted well to the experimental glucose release data under simulated gastric conditions (SGC) and SIC, respectively ($R^2 = 0.858–0.991$). After digestion under SIC, the consistency coefficient ($k$) values drastically decreased (73.02–90.27%), while the flow behavior index ($n$) increased (155.56–363.64%). Therefore, the amounts of glucose release can be controlled by manipulating the structure of native starches using chemical modifications such as cross-linking and hydroxypropylation.

1. Introduction

Due to many nutritional, technological and textural advantages of starch in food products, it is receiving much more attention. Depending on the rate of digestibility, starches are classified into three categories consisting of rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS).1 Consuming starchy foods containing large amounts of RDS causes a rapid raise in the blood glucose level which is followed by an increase in insulin response after ingestion.2,3 Therefore, considering a meal with more SDS or RS will be healthier especially for diabetic people.4 The postprandial level of blood glucose is generally estimated using a characteristic named glycemic index (GI) which is associated with the response of the consumed food to that of a reference one.5 From the nutritional point of view, foods with lower GI values are considered as healthy ones which reduce the risk of many diseases such as diabetes, heart disease, some forms of cancers and so on.4,6

Starch modification which encompasses the alteration of physicochemical attributes of native starches can be exploited to improve their functionality.7,8 Different chemical reactions are involved in chemical modification of starch like cross-linking, oxidation, etherification and esterification. Among these chemical methods, hydroxypropylation has been commonly used to improve the clarity, swelling power and retrogradation characteristics of native starches. On the other hand, cross-linking can strengthen the stability of the starch against specific conditions such as low pH, high temperature and shear.8 It is well known that in vitro digestibility of native starches can be changed by physical and chemical modifications.9 Over the past two decades, many studies have addressed the issue of influence of starch modification on its digestibility.5,9–11 In the case of hydroxypropylated starch, Wootton and Chaudhry (1989)12 declared that substitution of a bulky hydroxypropyl group causes a decrease in in vitro digestibility of wheat starch. For hydroxypropylated pea starch, Hoover et al.13 found that by increasing the molar substitution (MS) up to 0.08, its digestibility decreased. Chung et al.14 reported that among the modified corn starches, the hydroxypropylated one showed the lowest digestibility values in the gelatinized state. In contrast, it has been observed that in the granular state, by increasing the level of hydroxypropylation, a pronounced increase occurs in enzymatic digestibility due to the weakening of the granular structure following chemical modification.14–16 It is reported that in the granular state, the cross-linking of starch with a mixture of sodium trimetaphosphate (STMP) and sodium tripolyphosphate (STPP) reduced the digestibility due to the enzymatic inhibitory effect.17 Similar results were obtained for cross-linked corn