Effects of hyaluronic acid on gelatinization properties and in vitro digestibility of wheat starch

Kangyu Wang [1], Yunhe Liu [1], Dong Han [1], Feng Huang [1], Chunhui Zhang [1*]

[1] Key Laboratory of Agro-Products Processing, Ministry of Agriculture and Rural Affairs, Institute of Food Science and Technology, Chinese Academy of Agricultural Sciences, Beijing, China;

* Correspondence author: E-mail: dr_zch@163.com.

I. INTRODUCTION

Starch gelatinization leads to the destruction of starch crystallization and the layered structure, resulting in the formation of continuous gels, which greatly impacts the texture or consistency of the starch-based product. In addition to gelatinization properties, starch digestibility is also an essential quality criterion. Reducing the degree of starch gelatinization decreases its digestibility during the initial stages of digestion. Inhibiting the activities of α-amylase and amyloglucosidase can delay starch digestion, reducing the rate of glucose absorption and lessening the rise of serum glucose levels. Hyaluronic acid (HA) can form intramolecular hydrogen bonds, creating a three-dimensional structure that traps water due to its excellent water absorption properties. Consequently, HA's properties may influence the rheological and digestive characteristics of starch. Treating animal feed with hyaluronic acid to reduce the pasting and digestibility of starch is an innovative approach that can enhance animal welfare and performance. By controlling the rate of starch digestion, it is possible to manage energy levels, improve gastrointestinal health, and tailor diets more closely to the metabolic needs of different animals, potentially improving their overall health and productivity.

II. MATERIALS AND METHODS

The wheat starch (WS, 99% purity) with a carbohydrate content of up to 85.48% and a water content of 10.07% was provided by Xinliang Flour Co., Ltd (Jiangsu, China). The HA were purchased from Baiyao Biotechnology Co., Ltd (Jiangsu, China) with an average molecular weight of 349.7±3.5 kDa and a polydispersity index (PDI, Mw/Mn) of 1.025. The chemical reagents were analytical grade.

The content of leached amylose was determined according to the method of Kong et al. (2022) [1], with some modifications. The thermal properties of WS and WS-HA were determined using a differential scanning calorimeter. Rheological properties were tested using a Fourier infrared spectrometer. Starch digestibility was determined according to Zhou et al. (2022) [2].

The study's results were analyzed using SPSS 25.0 software (SPSS Inc., Chicago, USA) and presented as mean ± standard deviation (SD). One-way analysis of variance (ANOVA), followed by the Duncan and Dunnett tests for multiple comparisons, was used to evaluate significant differences between groups. A p-value of < 0.05 was considered statistically significant.

III. RESULTS AND DISCUSSION

As shown in Table 1, the amount of leached amylose decreased with the increase of HA, indicating that HA could hinder the gelatinization process. With the increase of HA content, the consistency index (K) increased gradually, indicating that the addition of HA could reduce the viscosity of gelatinized starch and make it more fluid. The DO values of WS-HA increased with increasing HA concentration.

During digestion, the presence of HA had a noticeable impact on the starch fraction contents of WS (Figure 1A). The rapidly digestible starch (RDS) content decreased sharply from 60.20% to 47.78%, while there were notable increases in the levels of slowly digestible starch (SDS, from 13.05% to 21.52%) and resistant starch (RS, from 26.75% to 31.16%) in WS-HA gels as the concentration of HA increased ($p < 0.05$). This indicated a strong concentration-dependent suppressive effect of HA on WS digestion. The fluorescence intensity of α-amylase increased in the presence of HA (Fig. 9A and B), while the fluorescence intensity of amylosidase decreased slightly (Figure 1B and C). Based on the above results, the limited interactions of HA with enzymes indicate that its reduction of starch digestibility is mainly due to the formation of a physical barrier on the food surface and the inhibition of starch gelatinization.

Table 1 – Leached amylose, Gel properties, and DO values WS, WS-HA mixtures.

Samples	Leached amylose (%)	K ($Pa \cdot s^n$)	n	R^2	R1047/1022
WS	12.61±0.26^a	14.989±0.221^d	0.254±0.005^{bc}	0.983	1.05
WS-HA-120:1	10.24±0.36^b	26.576±0.650^c	0.236±0.012^{cd}	0.996	1.07
WS-HA-24:1	8.95±0.15^c	35.659±0.012^b	0.267±0.001^{ab}	0.966	1.07
WS-HA-12:1	8.51±0.23^c	36.929±0.108^b	0.276±0.012^{ab}	0.975	1.10
WS-HA-6:1	8.15±0.03^c	40.895±0.646^a	0.282±0.007^a	0.986	1.18

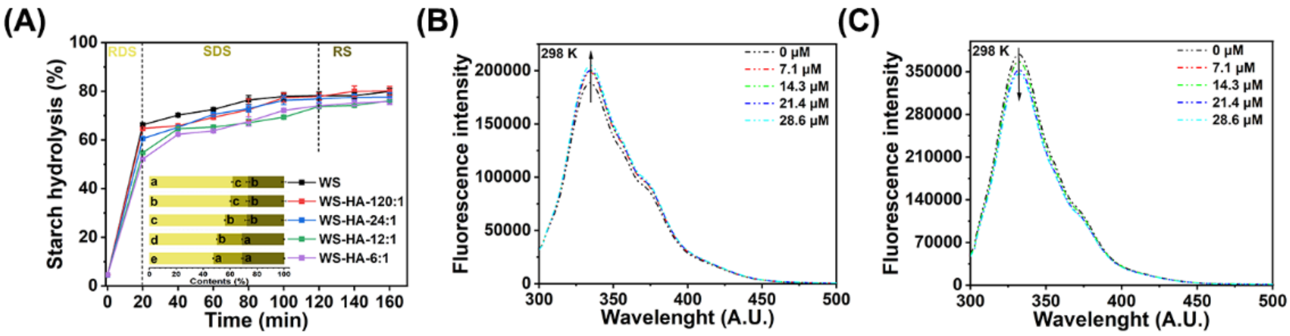

Figure 1. (A) Enzymatic hydrolysis curves and starch fraction distribution of the WS and WS-HA mixture. Letters indicate significant group differences ($p < 0.05$). Fluorescence quenching spectra of α-amylase (B) and amyglucosidase (C) in the presence of different concentrations of HA at 298 K.

CONCLUSION

In this study, the addition of HA inhibited starch gelatinization, increased the viscoelasticity and viscosity of WS-HA gels, and enhanced the ordering and stability of their network structure with increasing HA concentration. HA primarily reduces the degree of starch digestion by inhibiting starch gelatinization and preventing contact between enzymes and starch. These results can facilitate the use of HA in wheat starch foods.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support from the National Key R & D Program of China (2021YFD2100103), the Quality Livestock Product Industry Cluster-Key Technology Research and Integrated Demonstration for Yellow Feather Broilers Industry to Improve Quality and Efficiency (2022LQ01001) and the National Agricultural Science and Technology Innovation Project (CAAS-ASTIP-2023).

REFERENCES

Papers:

1. Kong, X.-R. (2020). Effects of Cordyceps polysaccharides on pasting properties and in vitro starch digestibility of wheat starch. Food Hydrocolloids, 102: 105604.
2. Zhou, J. (2022). Effects of Laminaria japonica polysaccharides on gelatinization properties and long-term retrogradation of wheat starch. Food Hydrocolloids, 133: 107908.