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Effect of high pressure in starch viscoelastic properties studied with an acoustic wave sensor

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Abstract

Unmodified native starches lack stability under temperature changes, shear, or pH. Food is often processed in order to induce modifications intended to improve the product and to give it the desired characteristics. Among the physical processing methods, high hydrostatic pressure is considered a mild technique with a big potential and it is nowadays used in a variety of products. Gelatinization of maize starch processed by high pressure was for the first time studied using an acoustic wave sensor. Besides a significant increase in amylopectin fusion temperature, other differences induced by pressure are visible on the frequency *vs*. temperature plot. Results from currently applied techniques are also shown, as only a combination of methodologies can contribute to a deep understanding of such a complex phenomenon as gelatinization.

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Keywords: maize starch; acoustic wave sensor; gelatinization; high pressure processing

1. Introduction

Starches are often used in food industry as texture modifiers, and their gelling and thickening properties are much appreciated. Their functional properties are dependent on their biological origin but also on the processes they have

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been through. It was shown that the use of homogenizers working at moderate pressures around 100 Pa did produce noticeable changes in the DSC thermograms of starches. Higher pressures would lead to larger changes in their gelatinization and pasting temperatures, as well as on the energy required to induce those phenomena. A complete characterization of the modified starch is far from being fulfilled with the available methodologies.

Acoustic wave sensors are much more than gravimetric devices. Their ability to detect biopolymer phase transitions, and to follow changes in starch viscoelastic properties induced by temperature, have already been shown [1,2]. They were here used to study the changes in maize starch after being processed at a pressure of 500 MPa over 5 minutes. The obtained complex signals can be very informative when decoded by combining information from other sources. Therefore, samples were also analyzed by microscopy and differential scanning calorimetry (DSC).

2. Materials and Instrumentation

2.1 Materials

Maize starch was obtained from the local supermarket. The starch suspensions (20% w/v) were prepared and high pressure treated at 500 MPa, over 5 minutes at room temperature, being then freeze dried. Native and treated starch suspensions (2.5% w/v) were prepared for analyses by dispersing the appropriate quantity of the desired starch in Milli-Q water, by stirring at room temperature for 30 minutes.

9 MHz AT cut, HC-6/U piezoelectric quartz crystals with gold electrodes were purchased at ICM – International Crystal Manufacturing Co, Inc.

2.2 Apparatus

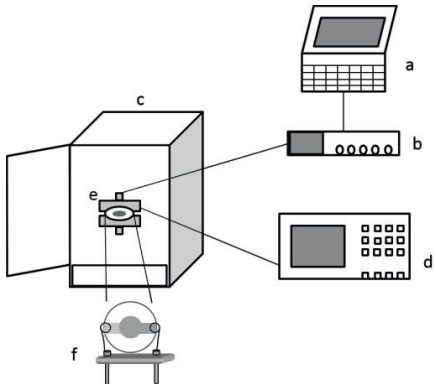

Fig. 1 Experimental layout used in acoustic wave sensor measurements: (a) personal computer; (b) multimeter connected to a PT100; (c) thermostatic chamber;(d) impedance analyzer: (e) teflon cell with (f) quartz crystal.

Fig. 1 shows the experimental layout. A piezoelectric quartz crystal was placed inside an home-made Teflon cell, filled with 1.00 mL of the starch suspension. The Teflon cell was placed inside a thermostatic chamber and a Pt 100 temperature sensor, immersed in the suspension, allows measuring the temperature. The piezoelectric quartz crystal was connected to an HP 4395A Network/Spectrum/Impedance Analyser (Hewlett-Packard) coupled with an HP 43961A impedance test kit and HP 16092A spring clip fixture.

Polarized light microscopy of maize suspensions was performed on an Olympus BH2-UMA with a hot stage Mettler FP82HT and a central processor Mettler FP90. Images were recorded with a camera Canon EOS 550D.

Maize suspensions were also analyzed on a differential scanning calorimeter Diamond DSC PerkinElmer.

3. Results and discussion

Fig. 2 shows electronic microscopy images of the maize starch granules before and after being processed at high pressure.

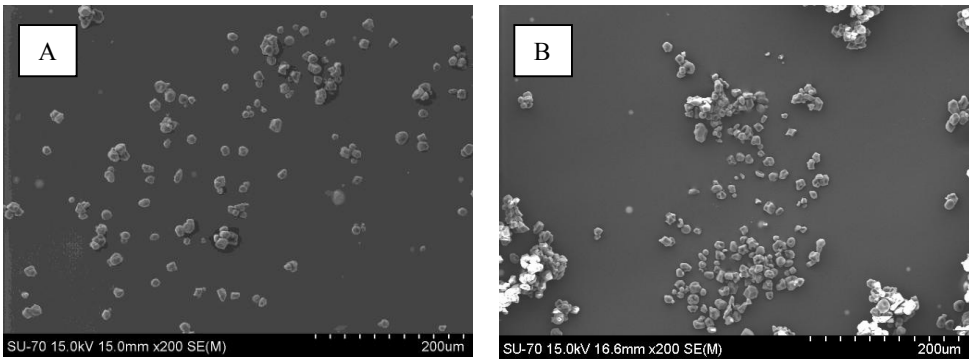

Fig. 2 SEM images of native (A) and high pressure treated maize starch (B).

It can be seen that after being processed at high pressure, granules were not disrupted and continue to exist as individual entities.

Fig. 3 shows the polarized light microscope images of the maize starch suspension treated by high pressure. The image shows birefringence in the form of the typical maltese cross. This is an evidence that after being processed at high pressure, the granules still keep a high degree of molecular order inside.

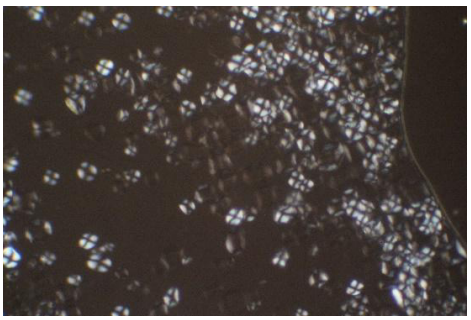

Fig. 3 – Polarized light microscope image of high pressure treated maize starch.

DSC has been very useful to study starch systems limited in water, where not many techniques can be used. Studies were conducted at heating rates of 20 ºC /min, as lower rates were not possible to run. Fig. 4 (A&B) shows the thermograms obtained with native maize starch and with starch processed at high pressure.

In Fig. 4, T peak is lower (73.07 ºC) for processed starch than for native starch (74.04 ºC), which shows that the chemical arrangement inside the granules has been changed with pressure. The energy required to melt the crystalline regions of the starch (gelatinization enthalpy) was also lower for the processed starch. No change on T onset, which has been related to the initiation of glass transition of the amorphous phase, was observed.

Fig. 5 shows the series frequency of the quartz crystal in contact with 2.5% (w/v) maize starch/water suspension, during heating and cooling cycle, both for native and pressure processed samples. The differences observed reflect the changes occurred within the granule under high pressure treatment.

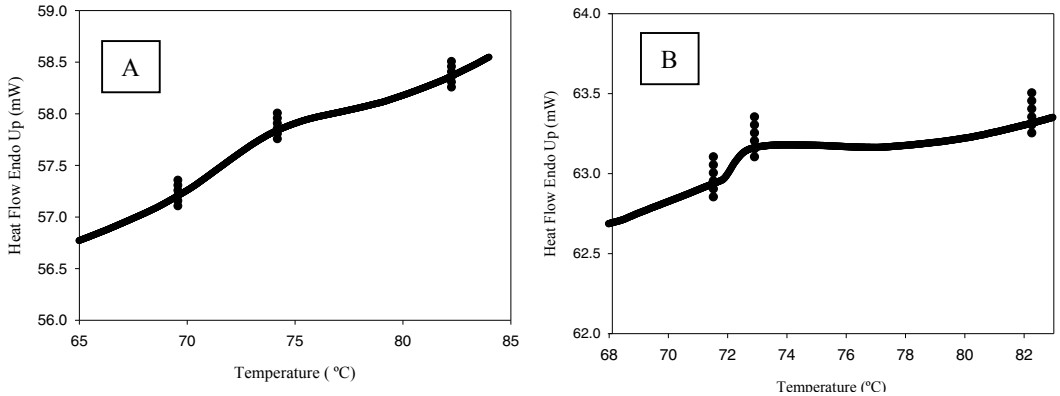

Fig. 4 DSC of native (A) and high pressure treated (B) maize starch.

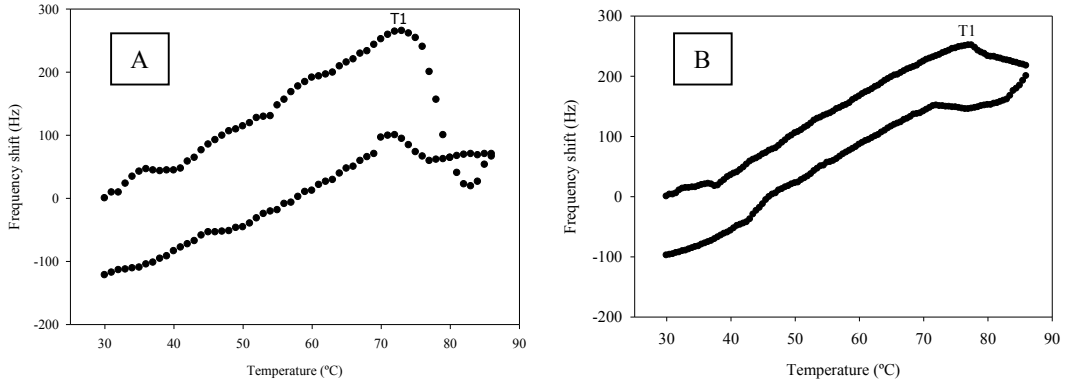

Fig. 5 Series frequency shift (Hz) of the quartz crystal in contact with native (A) and high pressure treated (B) maize starch suspension during heating (2.0 °C/min) and cooling.

It can be seen that T1, temperature of amylopectine fusion (gelatinization temperature, or pasting temperature, depending on the authors) increased with high pressure treatment of granules. However, the frequency decrease which occurs afterwards, as a consequence of the freeing of amylose trapped between the amylopectin layers, and to a smaller extent, confined within the crystalline amylopectin, is much smaller the one observed in native starch.

Although starch granules remained intact, it is not impossible that some amylose had already diffused out of granules before T1. In fact, in spite of the higher T1, frequency increased less before T1 for high pressure processed maize starch.

Similar studies with rice starch but at varying processing temperatures are currently being undertaken.

Acknowledgements

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