International Journal of Biological Macromolecules 91 (2016) 106–114

Contents lists available at ScienceDirect

International Journal of Biological Macromolecules

journal homepage: www.elsevier.com/locate/ijbiomac

Analysis of the pasting profile in corn starch: Structural, morphological, and thermal transformations, Part I

Natalia Rincón-Londoño[a], Lineth J. Vega-Rojas[b], Margarita Contreras-Padilla[c], A.A. Acosta-Osorio[d], Mario E. Rodríguez-García[e,*]

[a] Posgrado en Ciencias e Ingeniería de Materiales, Centro de Física Aplicada y Tecnología Avanzada, Universidad Nacional Autónoma de México, Campus Juriquilla, Querétaro, Qro, C.P 76230, Mexico
[b] Posgrado en Ciencias Químico Biológicas, Facultad de Química, Universidad Autónoma de Querétaro, Cerro de las Campanas S/N. Centro Universitario, C.P 76010 Querétaro, Qro, Mexico
[c] División de Investigación y Posgrado, Facultad de Ingeniería, Universidad Autónoma de Querétaro, Centro Universitario, C.P. 76010 Santiago de Querétaro, Qro, Mexico
[d] CONACYT Reseearch Fellow, Tecnologico Nacional de México, Instituto Tecnologico de Veracruz, Veracruz, Ver., Mexico
[e] Departamento de Nanotecnología, Centro de Física Aplicada y Tecnología Avanzada, Universidad Nacional Autónoma de México, Campus Juriquilla, Boulevard Juriquilla No. 3001 C.P. 76230, Juriquilla, Querétaro, A.P. 1-1010, Mexico

ARTICLE INFO

Article history:
Received 9 December 2015
Received in revised form 12 May 2016
Accepted 18 May 2016
Available online 19 May 2016

Keywords:
Gelatinization
Pasting
Starch
Retrogradation

ABSTRACT

This work is focused on the understanding of the apparent viscosity profile of corn starch, in terms of the physicochemical and morphological changes that take place during the thermal profile of starch-water suspension to its respective gel formation. A mathematical model was used to obtain the experimental operating conditions that satisfy the Froude number. Freeze drying samples are studied in different stages along the pasting profile. Changes in the structural properties of the samples are studied using X-ray diffraction, and the morphological changes are followed using scanning electron microscopy, differential scanning calorimetry was used to analyze the thermal changes in starch. The changes in the pasting profile are associated with structural, thermal,and morphological changes of the system and the analysis of the physicochemical transformation that occur during the pasting profile are explained. The finding in this work does not show evidence of gel retrogradation at the end of the cooling process.

1. Introduction

Starch is possibly the most important carbohydrate in modern human life, with different applications in industries such as the food, petroleum, pharmaceutical, paint, and cosmetic industries, among others. Starch is a granule or particle composed of two macromolecules: amylose and amylopectin [1,2]. Amylose has a linear structure of D-glucan units bonded together by α-(1,4) bonds, in the shape of a helix which consists of six fragments of glucose per turn [3]. On the other hand, amylopectin is a branched polymer that is composed of linear chains with α-(1–4) bonds and α-(1–6) bonds. Amylopectin structure consists of short chains forming double helices.

One of the most important aspects to study in the case of starch and its derivative products are the rheological and pasting properties. Pasting properties are often obtained by studying a pasting profile of a starch-water suspension, as a function of the time and temperature. The importance of characterizing the starch pasting profile is that many foods containing starch are cooked with water; this process causes great changes in the structure and morphology of the starch granules [4]. These changes result in some modified properties of the final product. Moreover, the swelling of the starch granules during cooking begins predominantly in amorphous regions [5]; this property is important because it allows the development of gel.The increase of apparent viscosity in starch-water suspensions occurs mainly due to the exudate products released from the starch granules forming a network [6]. Therefore, the effects of the thermal profile and the shear rate on the physicochemical properties of the starch-water suspension were not studied.

Wajira and and David [7] studied the gelatinization process of different native starches, using SEM, DSC, and X-ray diffraction followed by the micro, thermal, and structural transformations of starch-water suspension subjected to heating (35–85 °C at 5 °C

* Corresponding author at: Departamento de Nanotecnología, CFATA, UNAM, Querétaro, Qro, Mexico.
E-mail address: marioga@fata.unam.mx (M.E. Rodríguez-García).

http://dx.doi.org/10.1016/j.ijbiomac.2016.05.070
0141-8130/

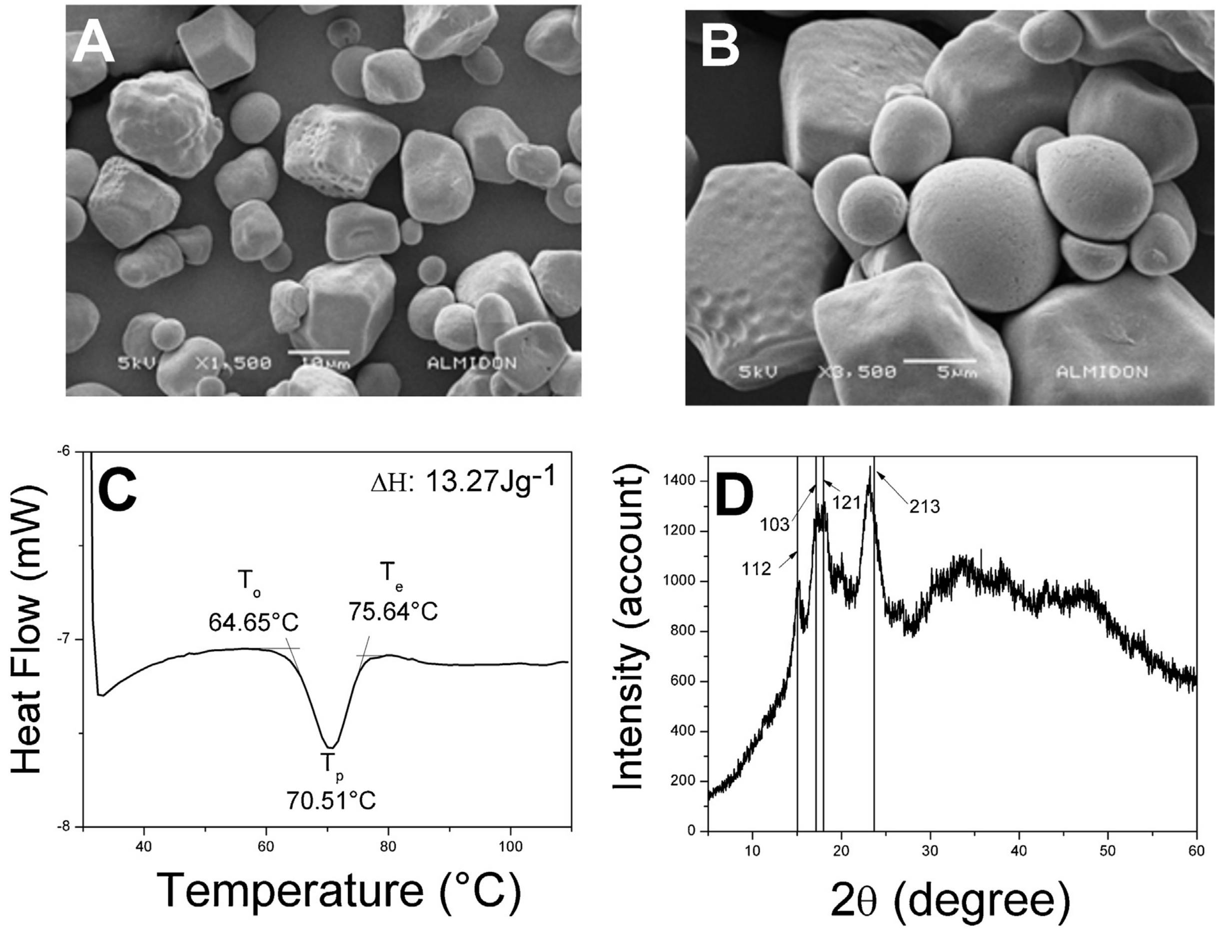

Fig. 1. (A) and (B) SEM images of isolated corn starch, (C) shows the DSC thermogram and (D) the characteristic X-ray diffraction pattern.

intervals). Their results showed that the gelatinization is not only an order-disorder transition between the amylose/amylopectin arranged inside the starch granule, but the disordered system can include the exudation of macromolecules. However, the pasting profiles of different starches and their morphological and structural changes as a function of the time during a pasting profile were not studied.

There are usually five sample characteristics, which are obtained with a pasting profile: peak viscosity and peak viscosity temperature; the ease of cooking; the paste stability or resistance to breakdown; setback or cold paste viscosity, and stability of the cooked paste. Additionally, the setback value may indicate the retrogradation tendency of the starch paste by part of components leachate [8]. However, these definitions were only phenomenological and no evidence of the physicochemical changes or the influence of these changes during a pasting profile, were reported. In the same direction, Karim et al. [9] defined the setback as the rapid retrogradation of leached amylose in the starch paste, but no evidence of the recrystallization (retrogradation) of amylose was reported.

The commercial system used to study pasting profiles is based on the principle given by the Rushton [10] equations, about the use of an impeller to study the rheological properties of a system. The basic viscometer impeller assumption is that the shear rate is independent of the rheological properties of the fluid. The experimental system can convert the torque reading into a shear stress/shear rate relationship.

In all the works above, even in an important number of researches related to the pasting properties of starches, it is not clear what kind of physicochemical changes take place during the pasting profile. There does not exist a detailed explanation of the changes in the morphology of the starch-water system as a result of the temperature and shear rate.

The objective of this work is to explain in detail the pasting profile of corn starch-water suspensions based on the physicochemical and morphological changes that take place during the thermal profile at the constant shear rate. For these experiments, corn starch was used. The Froude number (Fr = 1) was used to determine the experimental shear rate to carry out a pasting profile. Fr = 1 avoid precipitation of the starch granules because at this point gravity and inertia forces are equal. The morphological changes that take place along the pasting profile were studied using SEM with frozen samples; structural changes and thermal profiles were studied by means of X-ray diffraction and DSC respectively, for different points of the pasting profile.

2. Material and methods

2.1. Materials

Corn starch from Newport Scientific Pty Ltd. (part number 102102, Warriewood, Australia) was used in all experiments (see Fig. 1(A) and (B)). This regular starch contains 66% of amylopectin and 34% of amylose. Starch is characterized by a polyhedral morphology and some spherical granules between 4–12 μm. The chemical composition of the corn starch was the follows: the protein content was 0.67 ± 0.05%, fat content was 0.15 ± 0.02%, and fiber was not detected. The characteristic T_g of this starch was 70.51 °C (see Fig. 1(C)) the beginning of the thermal transforma-