Journal of Cereal Science 69 (2016) 194–198

Contents lists available at ScienceDirect

Journal of Cereal Science

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

Hydrothermal modification of wheat starch. Part 2. Thermal characteristics of pasting and rheological properties of pastes

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ARTICLE INFO

Article history:
Received 17 March 2015
Received in revised form
17 February 2016
Accepted 23 February 2016
Available online 3 March 2016

Keywords:
Wheat starch
Hydrothermal treatment
Freezing
Thermal characteristics of pasting
Rheology

ABSTRACT

Water suspensions of starch (with the concentration of 8 g/100 g) were prepared in a measuring vessel of a Brabender viscograph and heated to temperatures of 74, 76.5, 79, 81.5, 84, 86.5, 89, 91.5 or 94 °C under continuous stirring. The resultant solution was cooled and frozen, and then defrosted. Thermal characteristics of re-pasting, rheological properties of produced pastes, starch solubility in water and swelling power were determined.

The heating and freezing of the wheat starch suspension induced changes in its properties, with tendency and extent of these changes depending on temperature of pre-heating. The thermal characteristics of the analyzed starches revealed three peaks that corresponded to transitions proceeding during solubilization of retrograded amylopectin and retrograded amylose and solubilization of amylose –lipid complexes. Retrogradation of amylose induced by starch pre-heating followed by its freezing affected also the consistency coefficient and yield stress of the pastes formed by the analyzed starches. Values of these rheological parameters were higher at higher temperatures of pre-heating, compared to the pastes prepared from native starch, and were changing accordingly to the determined second order polynomial function. Amylose retrogradation occurring during the production of starch preparations diminished their solubility in water and increased their swelling power compared to native starch.

1. Introduction

Starch is a natural renewable polymer that serves the role of storage material in plants. Starches of various botanical origin differ in terms of appearance, internal structure, chemical composition and physicochemical properties (Zięba, 2009). Apart from the nutritive role, native starch present in plant products plays also the texture-forming role in finished food products, e.g. by forming the porous structure of bread with gluten. It may also be added to many food products in order to, e.g., impart them desirable viscosity like in a gelatin dessert and instant type products. The applicability of native starch in food production process is low owing to low viscosity of formed pastes, its susceptibility to retrogradation during storage and small resistance to low pH of the medium or mechanical factors (Ellis et al., 1998). For this reason, large part of starch is subjected to enzymatic, chemical or physical modifications (Synowiecki, 2007; Tomasik and Schilling, 2004; BeMiller, 1997). Many authors have undertaken studies on starch modifications aimed at improving its properties and at enabling wider industrial use of the modified preparations. Our earlier works (Gryszkin et al., 2014, 2016) present results of investigations in which a water dispersion of starch was heated, then frozen and defrosted. They demonstrated an increase in pastes viscosity during re-pasting of hydrothermally-modified starch and a correlation between viscosity of particles (gel sacks) present in the paste and its viscosity. Noteworthy is that changes in pastes viscosity were greater in the case of wheat than potato starch. For this reason, further studies were undertaken on hydrothermally-modified wheat starch.

This study was aimed at determining the effect of heating a water dispersion of wheat starch to various temperature, followed by its freezing and defrosting on the thermal characteristics (DSC) of re-pasting, as well as rheological properties, solubility in water and swelling power of prepared pastes.

2. Materials and methods

2.1. Material

The initial experimental material was C*Gel 20006 wheat starch

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http://dx.doi.org/10.1016/j.jcs.2016.02.012
0733-5210/

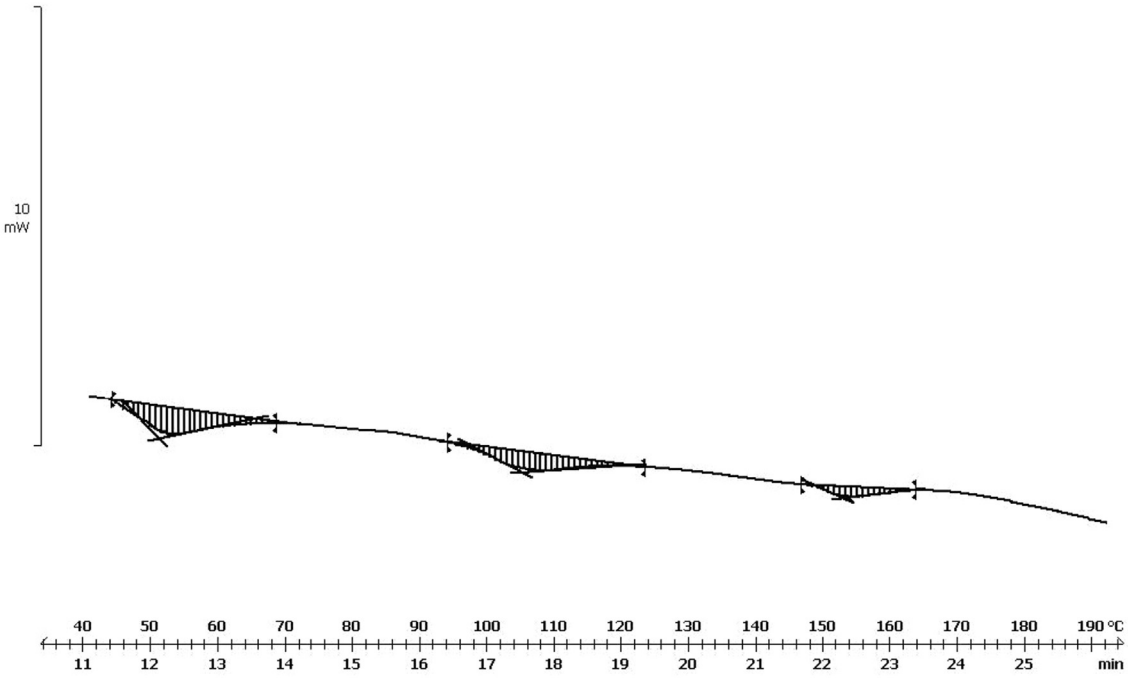

Fig. 1. Exemplary graph of thermal characteristic of wheat starch gelatinization DSC subjected to heating (till 89 °C) then freezing.

produced by Cargill Benelux company (The Netherlands) in 2012.

2.2. Preparations production procedure

450 ml of a water suspension of starch were prepared from native wheat starch in a measuring flask of a Brabender viscograph (Germany), with the concentration of 8 g/100 g, The suspension was heated to temperatures of 74, 76.5, 79, 81.5, 84, 86.5, 89, 91.5 or 94 °C at the rate of 1.5 °C/min under continuous stirring. The resultant solution was cooled to 30 °C at the rate of 1.5 °C/min, frozen for two days at −20 °C in a freezer (Bosch, Poland), and then defrosted for two hours at 40 °C in a water bath (Memmert, Germany). The native starch (non-modified hydrothermally) was assigned the symbol WNS, whereas starches subjected to preheating were assigned the following symbols: W74, W76.5, W79, W81.5, W84, W86.5, W89, W91.5 or W94 (where the digit standing after "W" letter denotes temperature to which starch suspension had been heated before freezing).

2.3. Determination of thermal characteristics using DSC technique

Thermal characteristics was determined according to the method by Gryszkin et al. (2014). The modified preparations (produced as in point 2.2) were dried in an air dryer (Memmert, Germany) at 30 °C for 24 h, ground and sieved through a screen with mesh size of 400 μm. Determination was conducted using a DSC 822E differential scanning calorimeter (Mettler Toledo, Germany). Before the measurement, the calorimeter was calibrated using iodine and zinc samples. Next, 10 mg of the analyzed sample (on dry matter basis) was placed on the bottom of a measuring vessel (MEDIUM PRESSURE ME-29990), then redistilled water was added at the ratio of 3:1 (water:starch). Next, the vessel was closed and the sample was conditioned at 25 °C for 30 min. The analysis was performed in a temperature range of 25°C–200 °C, with a heating rate of 10 °C/min. The DSC characteristics of pasting allowed determining (using StarSoftware by Mettler Toledo) the heat of transition as well as initial and end temperatures of pasting.

2.4. Determination of flow curves of starch pastes

The flow curves of starch pastes were determined according to the method by Zięba et al. (2011) with modifications. Analyses were conducted using a RS6000 Rheostress oscillating-rotating viscosimeter (Haake, Germany). Paste was sampled after completed

Table 1
Parameters of phase transitions of native and modified starches determined from thermal characteristics (DSC).

Type of preparation	Initial temperature [°C]			End temperature [°C]			Heat of transition [J/g]		
	I transition	II transition	III transition	I transition	II transition	III transition	I transition	II transition	III transition
WNS	53.40 ± 0.03^{f}	93.34 ± 0.17^{d}	–	65.97 ± 0.65^{g}	112.38 ± 0.27^{a}	–	8.15 ± 0.22^{d}	$0.78 \pm 0.09^{a,b}$	–
W74	45.50 ± 0.25^{e}	90.37 ± 0.23^{a}	–	56.33 ± 0.16^{c}	113.05 ± 0.21^{b}	–	1.62 ± 0.11^{a}	$0.79 \pm 0.07^{a,b}$	–
W76.5	$44.86 \pm 0.25^{c,d}$	95.98 ± 0.21^{g}	130.91 ± 0.33^{c}	57.51 ± 0.08^{d}	113.18 ± 0.24^{b}	163.62 ± 0.28^{c}	1.94 ± 0.43^{a}	0.65 ± 0.11^{a}	0.39 ± 0.09^{a}
W79	45.34 ± 0.12^{e}	96.80 ± 0.19^{h}	136.62 ± 0.27^{g}	58.51 ± 0.07^{e}	115.35 ± 0.17^{d}	167.60 ± 0.29^{e}	$2.81 \pm 0.09^{b,c}$	0.62 ± 0.07^{a}	0.66 ± 0.08^{c}
W81.5	42.32 ± 0.22^{a}	92.56 ± 0.11^{c}	134.52 ± 0.32^{e}	$56.01 \pm 0.05^{c,b}$	115.05 ± 0.28^{d}	169.88 ± 0.29^{f}	2.62 ± 0.18^{b}	0.98 ± 0.11^{b}	$0.48 \pm 0.09^{a,b}$
W84	43.52 ± 0.18^{b}	94.51 ± 0.17^{e}	128.50 ± 0.22^{b}	57.78 ± 0.11^{d}	112.5 ± 0.19^{a}	166.13 ± 0.21^{d}	2.42 ± 0.21^{b}	0.88 ± 0.07^{b}	$0.49 \pm 0.04^{a,b}$
W86.5	43.44 ± 0.27^{b}	96.15 ± 0.37^{g}	135.59 ± 0.13^{f}	$55.69 \pm 0.1^{a,b}$	114.41 ± 0.15^{c}	163.22 ± 0.25^{c}	2.68 ± 0.31^{b}	$0.79 \pm 0.08^{a,b}$	$0.59 \pm 0.06^{b,c}$
W89	$45.12 \pm 0.09^{e,d}$	92.04 ± 0.27^{b}	147.1 ± 0.15^{h}	59.96 ± 0.35^{f}	121.11 ± 0.19^{f}	161.23 ± 0.27^{b}	2.66 ± 0.03^{b}	2.45 ± 0.14^{d}	0.66 ± 0.07^{c}
W91.5	44.59 ± 0.21^{c}	95.08 ± 0.17^{f}	131.81 ± 0.18^{d}	56.40 ± 0.31^{c}	116.23 ± 0.16^{e}	175.99 ± 0.27^{g}	2.52 ± 0.04^{b}	$0.81 \pm 0.08^{a,b}$	1.08 ± 0.11^{d}
W94	43.73 ± 0.17^{b}	93.01 ± 0.12^{d}	125 ± 0.11^{a}	55.22 ± 0.21^{a}	122.65 ± 0.15^{g}	157.42 ± 0.12^{a}	3.18 ± 0.04^{c}	2.18 ± 0.07^{c}	0.34 ± 0.05^{a}
LSD	*0,37*	*0,38*	*0,43*	*0,52*	*0,39*	*0,51*	*0,41*	*0,17*	*0,15*

Mean values ± standard deviations are showed. Means in a column followed by the same letter are not significantly different ($P < 0.05$).