Food Sci. Biotechnol. Vol. 16, No. 5, pp. 832 ~ 835 (2007)

Food Science and Biotechnology

Effect of Microwave Irradiation on Crystallinity and Pasting Viscosity of Corn Starches Different in Amylose Content

Su-Jin Lee[1], Kawaljit Singh Sandhu, and Seung-Taik Lim*

School of Life Sciences and Biotechnology, Korea University, Seoul 136-701, Korea

[1]Department of Food Preparation, Daegu Polytechnic College, Daegu 706-711, Korea

Abstract Moisture content of normal, waxy, and high amylose corn starches was adjusted to 10-35%, and irradiated in a microwave oven. The effect of microwave irradiation on the crystalline structure of starch was measured by using a differential scanning calorimetry (DSC), and X-ray diffractometry. Pasting viscosity profile was also determined by using a rapid viscoanalyzer (RVA). For all the 3 types of starches tested, the rate of temperature increase by the microwave irradiation was faster and more rapidly reached the maximum temperature of the pressure bomb (120°C) when the moisture content was higher. X-ray diffraction and DSC data revealed that the microwave irradiated starch underwent partial disruption of crystalline structure. RVA studies showed that the irradiation caused significant reductions in maximal viscosity and breakdown, whereas pasting temperature was increased. Overall trends revealed that the microwave irradiation on the starch containing limited moisture content (less than 35%) provided the effects similar to the heat moisture treatment. These effects became more significant when the moisture content was higher. Compared to waxy corn starch, normal, and high amylose corn starches appeared to be more susceptible to the microwave irradiation.

Keywords: corn starch, microwave irradiation, crystallinity, pasting property

Introduction

Microwave is a nonionizing energy that causes a rise in the temperature within a penetrated medium as a result of rapid changes of the electromagnetic field at high frequency. Since the microwave irradiation is quite competitive in cost compared to other methods of heat processing, it has been used for thawing frozen foods, drying, baking, pasteurization, and sterilization for many food items (1). The various physical properties of the irradiated samples can mediate effects of microwave irradiation. In foods, factors to consider before irradiation include size, surface area, density, heat conductivity, etc. In case of liquid foods, viscosity, temperature, heat capacity, ion concentration, and charge size can mediate effects (2).

Microwave irradiation is applicable to starch processing, but it has not been used for this purpose on a commercial scale (3). Luo *et al.* (1) studied the effect of microwave irradiation on the physicochemical properties of normal, waxy, and high amylose corn starches after adding moisture to 30%. Lewandowicz *et al.* (3) studied the influence of microwave irradiation on the structural characteristics of potato and tapioca starches, and found the decrease in viscosity, and increase in gelatinization temperature when the moisture content was higher than 20%. Sumnu *et al.* (4) studied the microwave irradiation of wheat starch and reported that with a hydration level of 137.5 and 112.5%, the weight loss was 20 and 12.8%, respectively. Rosenberg and Bogl (5) reported the effect of microwave irradiation on bread and found the abnormal browning and unsatisfactory crust formation. Edwards (6) has reported that upon microwave irradiation of wheat kernels and flour, amylase activity and formation of gluten were reduced, whereas the water binding capacity and viscosity were increased. Uchijima and Kurihara (7) found that the retrogradation of starch was accelerated in the foods that underwent microwave irradiation. Kadlee *et al.* (8) used a microwave treatment to dry rice kernels and compared with conventional air drying. They reported that the microwave treatment was more effective than the air drying, but more starch was damaged.

Most of the microwave studies have been done on the starches containing amylose less than 35% (3) and at relatively high moisture contents (9). In this study, normal, waxy, and high amylose corn starches were examined at limited moisture contents (10-35%). The heating and irradiation effects on the crystalline structure and pasting viscosity of the starches were measured.

*Corresponding author: Tel: 82-2-3290-3435; Fax: 82-2-921-0557
E-mail: limst@korea.ac.kr

Received May 17, 2007; accepted July 12, 2007

Materials and Methods

Materials Normal and waxy corn starches were obtained from Samyang Genex Company (Seoul, Korea). High amylose (70%) corn starch was provided by Cerestar USA (Hammond, IN, USA).

Microwave irradiation The moisture content of each starch sample was adjusted to 10, 20, 30, and 35% by drying in a convection oven (45°C) or by adding water. Ten g of each starch sample was transferred in a polycarbonate microwave bomb (model 4782; Parr Instrument Co., Moline, IL, USA), and irradiated in a commercial microwave oven (frequency 2,450 MHz, output 650 W, Kenmore, Hoffman Estates, IL, USA) for 3 min. The temperature of the sample was measured during operation of the microwave oven using Han Young DX3 temperature controller (Seoul, Korea) and a K type CA thermocouple (Dong Yang Sensor, Seoul, Korea).

Pasting properties The pasting viscosity of starch samples was evaluated with rapid viscoanalyzer (RVA-3D; Newport Scientific, Warriewood, Australia). Starch suspensions (7%, w/w; 28 g total weight) were heated using a programmed heating and cooling cycle: heating from 25 to 95°C at a rate of 5°C/min, holding at 95°C for 10 min, cooling to 50°C at 5°C/min, and holding for 10 min.

X-ray diffraction The X-ray diffraction analysis was conducted using an X-ray diffractometer (M03XHF22; MAC Science Co., Yokohama, Japan). Copper (Cu) was used as the metal target and Ni as the filter. The X-ray diffractometer was operated at voltage and current of 40 kV and 30 mA, respectively. The diffraction was measured at the measurement angle (2θ) from 3 to 40° at a scanning speed of 1°/min.

Thermal properties The melting temperature and melting enthalpy of starch samples were measured using a differential scanning calorimeter (DSC6100; Seiko Instruments Inc., Chiba, Japan). Indium (melting point: 156.6°C) was used to adjust the temperature and empty aluminum pan was used as references. Each sample (2 mg) was added to an aluminum pan, and distilled water was added to obtain starch:water (1:4). The pan was then sealed and heated at a speed of 10°C/min from 20 to 170°C, and the melting endothermic curves were recorded.

Statistical analysis The data reported in the Table 1 was subjected to one-way analysis of variance (ANOVA) using Minitab Statistical Software version 15 (Minitab, Inc., State College, PA, USA).

Results and Discussion

Heating effect by microwave irradiation The time-temperature profile with a variation in moisture content for microwave irradiated waxy corn starch is shown in Fig. 1. The profiles for normal and high amylose corn starches were similar (data not shown).

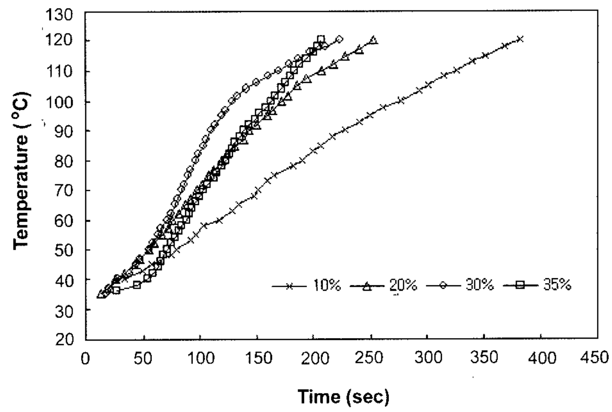

Fig. 1. Time-temperature profile of microwave irradiated waxy corn starch at different moisture contents (10-35%).

Foods are dielectric substances, and the dielectric constant (ε') and dielectric loss factor (ε") plays an important roles in microwave irradiation. Foods with large dielectric loss factors can be readily heated by microwave, and the parameters like compositions, microwave frequency have an impact on microwave efficiency.

For the starches tested, the rate of temperature increase was higher for the samples with higher moisture content. Therefore, water friction determines the elevation of the temperature, and samples with abundant amounts of polarized water have a rapid increase in heating rates. Similar findings of higher temperature rise with higher moisture content have been reported for corn starch by Stevenson *et al.* (10). The temperature reached the maximum temperature for the sample bomb (120°C) within 7 min.

Pasting properties The viscosities of microwave irradiated starches during pasting are shown in Table 1. High amylose corn starch, both native and treated, did not show pasting viscosity. The pasting temperature of normal

Table 1. Pasting properties of native and microwave irradiated normal and waxy corn starches at different moisture contents (10-35%)[1)]

Starch	Pasting temperature (°C)	Peak viscosity (mPa·sec)	Breakdown (mPa·sec)	Setback (mPa·sec)	Final viscosity (mPa·sec)
Native normal corn	84.65_c	825_c	255_b	296_c	866_e
10%	85.10_c	881_c	287_c	336_d	930_f
20%	87.05_d	841_c	243_b	326_d	924_f
30%	89.80_e	439_b	38_a	151_b	552_b
35%	90.60_f	308_a	27_a	131_b	412_a
Native waxy corn	70.30_a	1802_g	1151_f	128_b	779_d
10%	70.25_a	1264_d	768_d	93_a	589_{bc}
20%	70.40_a	1327_e	819_e	98_a	606_c
30%	70.30_a	1336_e	827_e	112_{ab}	621_c
35%	71.35_b	1665_f	1110_f	117_{ab}	672_{cd}

[1)]Each value represents the mean of triplicates. Data with different subscripts in a column were significantly different ($p<0.05$).

and waxy corn starches in viscogram was increased by microwave irradiation (from 84.65 to 90.60°C, and from 70.30 to 71.35°C, respectively). The pasting temperature increase was more significant when the moisture content was higher. Stevenson *et al.* (10) also reported that the pasting temperature of corn starch was raised by microwave irradiation, and the change was higher at 40% moisture content as compared to those at moisture contents of 15-35%.

Irradiated starches showed reduced peak and breakdown viscosities as compared to its native counterparts. These changes in viscosities were greater for normal starch than those for waxy starch. There were increases in final viscosity for the normal corn starches irradiated at 10 or 20% moisture, but those were minor (Table 1). Native normal corn showed a breakdown of 255 cp whereas microwave irradiated counterpart with a moisture content of 35% showed the value of 27 cp. The reduced breakdown illustrated that the swollen starch granules became more stable against to the shearing at high temperature.

Overall data indicate that the residual water in starch accelerates the viscogram changes induced by microwave treatment. And normal corn starch appeared more susceptible to the irradiation than waxy starch.

X-ray diffraction The X-ray diffractograms of native and microwave irradiated normal, waxy, and high amylose corn starches are shown in Fig. 2. Normal and waxy corn starches showed an A-type pattern whereas high amylose corn starch showed a B-type pattern. The crystalline pattern did not change with microwave irradiation. However, small decrease in crystallinity was observed with the irradiated starches. Native normal corn starch showed the doublet at 17.2 and 18.0° (2θ) which became less pronounced in its microwave irradiated counterparts. The disruption of the crystalline structure was more obvious when the moisture content was higher. High amylose corn starch showed the loss in crystallinity at 5 and 15° (2θ), and doublets at 22 and 23° (2θ) were also merged into one peak by microwave irradiation. The loss of crystal structure by microwave was more substantial for high amylose corn starch than those for normal or waxy corn starches.

The reduced viscosity shown on viscograms might be due to the decrease in crystallinity (Table 1). Also, as shown on the pasting viscosity results, the crystallinity decrease on X-ray diffractograms was positively related with the residual moisture content in the starch samples.

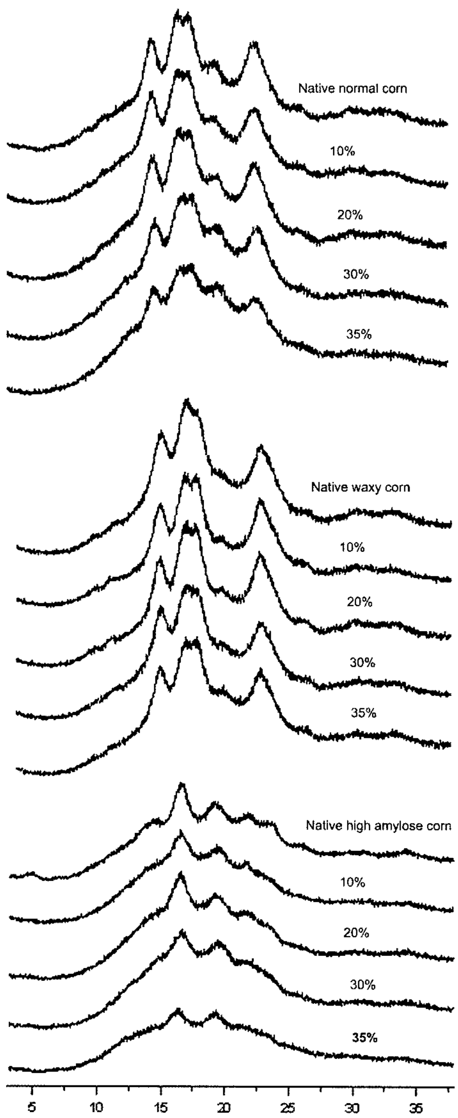

Fig. 2. X-ray diffraction patterns of native and microwave irradiated normal, waxy, and high amylose corn starches at different moisture contents (10-35%).

Thermal properties The thermograms of the microwave irradiated normal and waxy corn starch samples at different moisture contents measured by using a DSC are shown in Fig. 3. High amylose corn starch showed broad melting which was not reproducible (data not shown). The onset, peak, and conclusion temperatures for melting for both normal and waxy corn starch samples were elevated by microwave irradiation and the increase was positively related with the moisture content. These changes supported that the starch underwent the annealing effects as observed in heat moisture treatment (11, 12). Luo *et al.* (1) recently reported that microwave treatment at 30% moisture content increased the gelatinization temperature of maize starches. It has been suggested that the changes occurred in the heat moisture treatment was due to the association of the amorphous chains or reconfiguration in granular structure, which resulted in greater stability (12). The increase in pasting temperature by irradiation measured by RVA was well correlated with the increase in T_0 measured by DSC. DSC results showed that the melting enthalpy (ΔH) of normal and waxy corn starches was decreased by the microwave irradiation. The enthalpy decrease was also more significant as the moisture content in the sample increased. Stevenson *et al.* (10) reported a marked decrease in ΔH for normal corn starch when irradiated at 35 and 40% of moisture. The DSC results in melting enthalpy agreed well with the X-ray results: reduced crystallinities. Microwave irradiation induced temperature increase for starch, which provided similar effects to heat-moisture treatment, resulting in both partial disruption and reconfiguration of crystalline structure. As shown in the

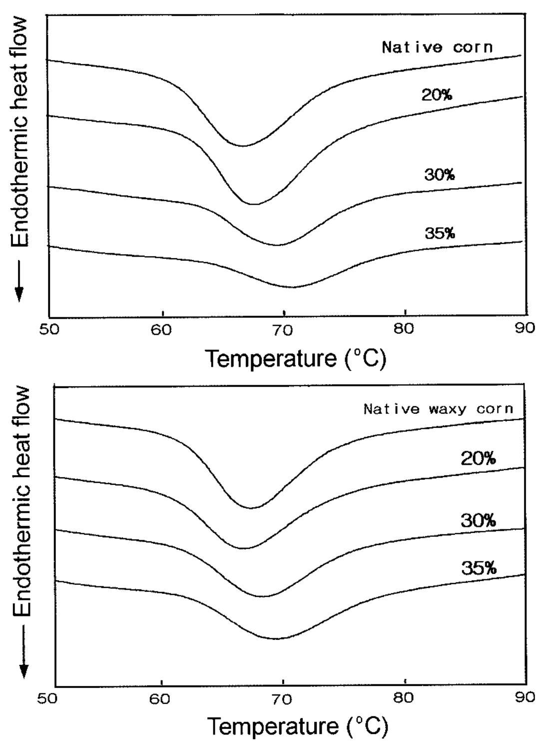

Fig. 3. DSC thermograms of native and microwave irradiated normal and waxy corn starches at different moisture contents (20-35%).

heating profile, the heating induced by microwave was accelerated by the residual moisture, and thus the starch samples containing higher amount of moisture exhibited the more changes in pasting viscosity and crystalline structure.

However, it is still unknown why the starch containing more amylose was more susceptible to the microwave irradiation. One possible explanation would be that amylose chains reside mostly in the amorphous regions in starch granule where the irradiation could readily reach. More study should to be done for clear understanding.

References

1. Luo Z, He X, Fu X, Luo F, Gao Q. Effect of microwave radiation on the physicochemical properties of normal maize, waxy maize, and amylomaize V starches. Starch 58: 468-474 (2006)
2. Decareau RV. Microwave Foods: New Product Development. Food and Nutrition Press., Inc., Trumbull, CT, USA. pp. 1-213 (1992)
3. Lewandowicz G, Fornal J, Walkowski A. Effect of microwave radiation on physico-chemical properties and structure of potato and tapioca starch. Carbohyd. Polym. 34: 213-216 (1997)
4. Sumnu G, Ndife MK, Bayindirh L. Temperature and weight loss profiles of model cakes baked in the microwave oven. J. Microwave Power EE 34: 221-226 (1999)
5. Rosenberg U, Bogl W. Microwave thawing, drying, and baking in the food industry. Food Technol.-Chicago 41: 85-91 (1987)
6. Edwards GH. Effect of microwave radiation on wheat and flour: The viscosity of flour pastes. J. Sci. Food Agr. 15: 108-114 (1964)
7. Uchijima Y, Kurihara Y. The retrogradation of starch of electronic range heated food. J. Home Econ. Jpn. 28: 95-99 (1977)
8. Kadlee P, Kaasova J, Bubnik Z. Chemical and physicochemical changes during microwave treatment of rice. Food Sci. Biotechnol. 12: 219-223 (2003)
9. Miller LA, Gordon J, Davis EA. Dielectric and thermal transition properties of chemically modified starches during heating. Cereal Chem. 68: 441-448 (1991)
10. Stevenson DG, Biswas A, Inglett GE. Thermal and pasting properties of microwaved corn starch. Starch 57: 347-353 (2005)
11. Lorenz K, Kulp K. Physico-chemical properities of defatted heat-moisture treated starches. Starch 35: 123-129 (1983)
12. Donovan JW, Lorenz K, Kulp K. Differential scanning calorimetry of heat-moisture treated wheat and potato starches. Cereal Chem. 60: 381-387 (1983)