

Effect of Pericarp Removal on Properties of Wet-Milled Corn Starch

Ya-Jane Wang,^{1,2} Sheau Wen Chong,¹ and Wade Yang³

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The most important step in the conventional corn wet-milling operation is steeping—the soaking of corn kernels in an aqueous solution containing 0.1–0.2% sulfur dioxide (SO₂) and 0.5–1.5% lactic acid at 45–55°C for 24–40 hr (Shandera and Jackson 1996). The main function of SO₂ is to cleave the disulfide bonds in the protein matrix that encapsulates the starch granules (Watson 1984). The long steeping time in the current wet-milling process is mainly attributed to the long diffusional path of SO₂ into the endosperm. Because steeping and steepwater evaporation account for the majority of energy consumption in the conventional wet-milling process, there are continuing efforts to develop alternative wet-milling procedures to shorten the steeping time and to reduce the volume of steepwater needed.

To reduce the diffusional path length, pericarp can be removed or the corn kernel can be cracked apart to increase surface area and to allow for better moisture and SO₂ penetration. Lopes-Filho et al (1997) developed a process called “intermittent milling and dynamic steeping” as an alternative method to the conventional process. This process required only 5 hr of steeping and produced on average 1% greater starch yield than the conventional process. However, this process resulted in a lower germ oil recovery. Recently, Yang et al (2002) developed an ultrasonic method to remove corn pericarp. The pericarp was easily removed after corn kernels were sonicated for 3 min. After the pericarp was removed, the pericarp-free kernels could then be wet-milled to yield starch. When the pericarp is intact, water and SO₂ can only channel through the tip cap (the attachment to the cob) to penetrate the kernel. After removal of the pericarp, it is possible for moisture and SO₂ to migrate easily into the kernel to expedite the hydration rate. Therefore, this study was conducted to investigate the effect of pericarp removal by high-intensity ultrasound on corn kernel hydration as measured by changes in the physicochemical properties of the isolated starch.

MATERIALS AND METHODS

Material

Yellow dent corn was obtained from Cargill, Inc. (Dayton, OH). Corn kernels were cleaned to remove any foreign objects, and broken, moldy, and heat-damaged kernels. Cleaned kernels were packed in individual sample bags (100 g) and stored at 4°C until use. All chemicals were ACS grade.

Pericarp Removal by Sonication

The sonication and pericarp removal treatment followed the procedure of Liu (2002) and Yang et al (2002). Corn kernels (100 g) were placed in a 20-qt resealable plastic bag and then the bag was filled with 3L of water. After sealing the bag with air squeezed out, the bag was placed in a 20.8L sonicator tank (Zenith Ultra-

sonics, Norwood, NJ) filled with water to about an inch below the rim of the tank. The sample was sonicated for 3 min at room temperature at the specifications of the sonicator of a frequency and power of 40 kHz and 925W, respectively. After sonication, the corn kernels were blotted dry with a paper towel, the pericarp of the dried kernels was manually separated from the endosperm with a paring knife, and the debranned kernels were stored in individual bags at 4°C before wet-milling.

Wet-Milling

A 100-g laboratory wet-milling procedure developed by Singh et al (1997) was used in this study with modifications. Both pericarp-intact samples (controls) and pericarp-free samples were subjected to the wet-milling process. Kernels (50 g) were steeped in 100 mL of steeping solution containing 0.2% SO₂ (w/w) and 0.5% (w/w) lactic acid at 50°C for different periods of time. The pericarp-intact samples were steeped for 1 and 48 hr, and the pericarp-free samples were steeped for 1, 6, and 48 hr.

After steeping, the steepwater was drained, and germ was separated from the kernels using a paring knife. Deionized water (200 mL) was added to the germ-free kernels and then coarsely ground using a Waring blender (Torrington, CT) at a speed of 18,000 rpm for 2 min. The ground slurry was screened through a 1.18-mm sieve, and 300 mL of deionized water was used to rinse the coarse fiber that was left on the sieve. The filtrate and wash water were combined and blended again in the blender. The slurry was screened through a 75- μ m sieve and allowed to settle at room temperature for 30 min. The top liquid portion was decanted, and the remaining portion was centrifuged at 1,400 \times g for 15 min. After centrifugation, the top yellowish protein layer was carefully removed with a spatula, and the starch layer was reslurried with deionized water and centrifuged. The starch layer was washed with deionized water again, centrifuged, and dried at 40°C overnight.

Physicochemical Properties of Isolated Starch

The moisture, residual protein, and damaged starch of the isolated starch were determined according to Approved Methods 44-19, 46-13, and 76-31, respectively (AACC International 2000). Damaged starch content was determined using a test kit (Megazyme Co., Wicklow, Ireland).

The gelatinization characteristics of the samples were assessed using differential scanning calorimetry (DSC) (Pyris-1, Perkin-Elmer, Norwalk, CT). Starch (\approx 4 mg, db) was placed in a DSC aluminum pan and 8.0 μ L of deionized water was added with a microsyringe. The aluminum pan was hermetically sealed, equilibrated at room temperature for at least 1 hr, and then scanned from 20 to 120°C at a rate of 10°C/min. The onset and peak temperatures and the enthalpy of the gelatinization endotherm were computed.

The pasting properties of isolated starches were measured with a Rapid Visco Analyser (RVA) (Newport Scientific, Sydney, Australia). Starch suspensions of 7.0% (db) with a total weight of 28 g were subjected to an established temperature-time profile. The starch slurry was heated from 50 to 95°C and then cooled from 95 to 50°C at 12°C/min and 160 rpm. Peak, breakdown, final, and setback viscosities were recorded. All measurements were performed in duplicate.

¹ Department of Food Science, University of Arkansas, Fayetteville, AR 72704.

² Corresponding author. Phone: 479-575-3871. Fax: 479-575-6936. E-mail: yjwang@uark.edu

³ Department of Food and Animal Sciences, Alabama A&M University, Normal, AL 35762.

TABLE I
Residual Protein, Damaged Starch, Gelatinization Characteristics, and Pasting Properties of Isolated Starch from Different Treatments^a

	Pericarp-Intact Corn		Pericarp-Free Corn		
	1-hr Steeping	48-hr Steeping	1-hr Steeping	6-hr Steeping	48-hr Steeping
Residual protein (% db)	0.63b	0.39c	0.61b	0.36c	0.78a
Damaged starch (% db)	0.40a	0.35a	0.11b	0.08b	0.40a
Onset gelatinization (°C)	66.8c	70.9b	67.4c	73.4a	72.1ab
Peak gelatinization (°C)	71.9c	75.4b	72.9c	76.9a	76.4ab
Gelatinization range ^b (°C)	12.3a	9.9c	11.5b	8.1d	9.5c
Enthalpy (J/g)	10.2c	12.2a	11.0b	11.5ab	12.1a
Peak viscosity (cP)	1,519a	1,336c	1,487b	1,153e	1,217d
Breakdown viscosity ^c (cP)	445a	301b	426a	95d	171c
Final viscosity (cP)	1,637a	1,463b	1,646a	1,333b	1,358b
Setback viscosity ^d (cP)	563a	428b	585a	275c	312c

^a Mean values of duplicates followed by the same letter within the same column are not significantly different ($P < 0.05$).

^b Gelatinization range = end gelatinization temperature – onset gelatinization temperature.

^c Breakdown = peak viscosity – trough viscosity (not shown).

^d Setback = final viscosity – trough viscosity (not shown).

Statistical Analysis

Experimental data were analyzed using the SAS general linear models procedure (SAS Institute, Cary, NC), and least significance differences were computed at $P < 0.05$.

RESULTS AND DISCUSSION

The physicochemical properties of the isolated starch from different treatments are listed in Table I. Because of the lack of appropriate wet-milling equipment to properly mill the starch, the starch yields from different treatments are not included. The low residual protein and damaged starch content indicated the high purity of the isolated starch from different treatments. The residual protein content of the isolated starch decreased when the steeping duration increased, with the exception of the pericarp-free sample with 48-hr steeping, which had a higher protein content than the other two pericarp-free starch samples. The higher residual protein in this starch sample may have been due to either inconsistent operation in starch isolation or greater difficulty in distinguishing the protein layer from the starch layer for that particular sample.

When the gelatinization characteristics of the isolated starch from different treatments were compared, we noted that within the same treatment (pericarp-intact or pericarp-free) an increase in steeping time resulted in an increase in onset and peak temperatures and enthalpy but a decrease in gelatinization range. These results indicated that the starch samples that were steeped for 6 and 48 hr possessed the characteristics of annealed starch. It is well known that corn starch goes through an annealing process during wet-milling. Annealing is a physical treatment that involves incubation of starch granules in excess water (>60% water based on starch weight) for a certain period of time at a temperature above the glass transition temperature but below the gelatinization temperature of starch. It has been well documented that annealed starch displays a narrower gelatinization range and higher gelatinization temperatures than its native starch (Krueger et al 1987; Knutson 1990; Jacobs et al 1995, 1997; Eerlingen et al 1996; Nakazawa and Wang 2003). The gelatinization enthalpy can be either higher (Kruger et al 1987; Knutson 1990; Jacobs et al 1995; Eerlingen et al 1996) or remain unchanged (Yost and Hosney 1986; Jacobs et al 1995, 1997; Eerlingen et al 1996; Larson and Eliasson 1991) after annealing.

The pericarp-free sample with 1 hr of steeping showed slightly, although not significantly, higher onset and peak gelatinization temperatures and significantly lower gelatinization range. The removal of pericarp could not instantaneously improve water penetration and endosperm hydration. Nevertheless, the significantly lower gelatinization range did imply that the improvement of corn kernel hydration could be observed after only 1 hr of steeping with the removal of pericarp. The significance of pericarp removal

in facilitating endosperm hydration was clearly demonstrated when comparing the pericarp-intact sample with 48-hr steeping against the pericarp-free sample with 6-hr steeping. The significantly higher onset and peak temperatures and enthalpy and significantly lower gelatinization range of the pericarp-free sample indicated that starch in this pericarp-free sample went through a longer annealing period because the steeping temperature was 50°C for all treatments, consequently resulting in higher gelatinization temperatures. Similar onset and gelatinization temperatures for pericarp-free samples with 6-hr steeping and 48-hr steeping suggested that corn kernels could reach the maximum hydration after 6 hr of steeping if the pericarp were removed.

The pasting properties of the isolated starch followed a similar trend as the gelatinization characteristics for different starch samples. Both pericarp-free and pericarp-intact samples shared similar pasting properties after steeping for 1 hr. The pericarp-free samples with 6-hr steeping and 48-hr steeping exhibited lower peak, breakdown, final, and setback viscosities, indicating a greater extent of annealing. The pasting properties supported the previous results for gelatinization properties that starch in pericarp-free corn kernels experienced a longer period of annealing due to improved hydration from the removal of the pericarp.

This study demonstrated that pericarp removal before steeping significantly reduced the steeping time. The pericarp-free corn kernels hydrated faster than the pericarp-intact corn kernels and could reach complete hydration after 6 hr of steeping. Gelatinization properties as measured by DSC can be used to monitor the extent of corn hydration during steeping.

LITERATURE CITED

- AACC International. 2000. Approved Methods of the American Association of Cereal Chemists, 10th Ed. Methods 44-15A, 44-18, 44-19. The Association: St. Paul, MN.
- Eerlingen, R. C., Jacobs, H., Van Win, H., and Delcour, J. A. 1996. Effect of hydrothermal treatment on the gelatinization properties of potato starch as measured by differential scanning calorimetry. *J. Thermal Anal.* 47:1229-1246.
- Jacobs, H., Eerlingen, R. C., Clauwaert, W., and Delcour, J. A. 1995. Influence of annealing on the pasting properties of starches from varying botanical sources. *Cereal Chem.* 72:480-487.
- Jacobs, H., Eerlingen, R. C., Spaepen, H., Grobert, P. J., and Delcour, J. A. 1997. Impact of annealing on the susceptibility of wheat, potato and pea starches to hydrolysis with pancreatin. *Carbohydr. Res.* 305:193-207.
- Knutson, C. A. 1990. Annealing of maize starches at elevated temperatures. *Cereal Chem.* 67:376-384.
- Krueger, B. R., Knutson, C. A., Inglett, G. E., and Walker C. E. 1987. A differential scanning calorimetry study on the effect of annealing on gelatinization behavior of corn starch. *J. Food Sci.* 52:715-718.
- Larson, I., and Eliasson, A. C. 1991. Annealing of starch at an inter-

- mediate water content. *Starch* 43:227-231.
- Liu, Z. 2002. Ultrasound enhanced corn pericarp separation process. MS thesis. Dept. of Food Science, University of Arkansas: Fayetteville, AR.
- Lopes-Filho, J. F., Buriak, P., Tumbleson, M. E., and Eckhoff, S. R. 1997. Intermittent milling and dynamic steeping process for corn starch recovery. *Cereal Chem.* 74:633-638.
- Nakazawa, Y., and Wang, Y.-J. 2003. Acid hydrolysis of native and annealed starches and branch-structure of their Naegeli amyloextrins. *Carbohydr. Res.* 338:2871-2882.
- Shandera, D. L., and Jackson, D. S. 1996. Effect of corn wet-milling conditions (sulfur dioxide, lactic acid, and steeping temperature) on starch functionality. *Cereal Chem.* 73:632-637.
- Singh, S. K., Johnson, L. A., Pollak, L. M., Fox, S. R., and Bailey, T. B. 1997. Comparison of laboratory and pilot-plant corn wet-milling procedures. *Cereal Chem.* 74:40-48.
- Watson, S. A. 1984. Corn and sorghum starches: Production. Pages 417-468 in: *Starch: Chemistry and Technology*, 2nd Ed. R. L. Whistler, J. N. BeMiller, and E. F. Pascall, eds. Academic Press: Orlando, FL.
- Yang, W., Liu, Z., and Siebenmorgen, T. 2002. Ultrasound processing of foods—A case study of corn component separation. ASAE Paper No. 026022. ASAE: St. Joseph, MI.
- Yost, D. A., and Hoseney, R. C. 1986. Annealing and glass transition of starch. *Starch* 38:289-292.

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