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Comparison of waxy and normal potato starch remaining granules after chemical surface gelatinization: Pasting behavior and surface morphology

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ABSTRACT

To understand the contribution of granule inner portion to the pasting property of starch, waxy potato starch and two normal potato starches and their acetylated starch samples were subjected to chemical surface gelatinization by 3.8 mol/L $CaCl_2$ to obtain remaining granules. Native and acetylated, original and remaining granules of waxy potato starch had similar rapid visco analyzer (RVA) pasting profiles, while those of two normal potato starches behaved obviously different from each other. All remaining granules had lower peak viscosity than the corresponding original granules. Contribution of waxy potato starch granule's inner portion to the peak viscosity was significant more than those of normal potato starches. The shell structure appearing on the remaining granule surface for waxy potato starch was smoother and thinner than that for normal potato starches as observed by scanning electron microscopy, indicating a more regular structure of shell and a more ordered packing of shell for waxy potato starch granules. The blocklet size of waxy potato starch was smaller and more uniform than those of normal potato starches as shown by atomic force microscopy images of original and remaining granules. In general, our results provided the evidence for the spatial structure diversity between waxy and normal potato starch granules: outer layer and inner portion of waxy potato starch granule had similar structure, while outer layer had notably different structure from inner portion for normal potato starch granule.

1. Introduction

Waxy potato starch is a potato mutant that is devoid of amylose (Luo, Huang, Fu, Zhang, & Yu, 2009; McPherson & Jane, 1999). This is proven by the absolute amylose content of 0% (McPherson & Jane, 1999). Waxy potato starch was found to resemble normal potato starch in B-type X-ray diffraction pattern, and the phosphorus contents to be primarily phosphate monoesters with no phospholipid (McPherson & Jane, 1999); as well as have advantages over normal potato starch, such as lower viscosity, enhanced stability and less turbid in pastes, and lower tendency to retrograde (Luo et al., 2009). Although waxy potato starch had a longer average chain length than waxy wheat and waxy maize starches (Cai & Shi, 2010), it displayed a lower proportion of long branch chains than did normal potato amylopectin (McPherson & Jane, 1999). Waxy potato starch was investigated on the preparation, physical and chemical properties of acetylated distarch adipate, the modified waxy potato starch paste exhibited excellent viscosity stability, acid resistant, salt tolerance properties and good breakdown (Luo et al., 2009).

Studies on the morphological changes of native granules by surface gelatinization with calcium chloride showed that waxy potato starch gelatinized significantly faster than normal potato starch (Koch & Jane, 2000). The surface-gelatinized starch granules investigated using scanning electron microscopy (SEM) exhibited rather evenly eroded granule surfaces for waxy and normal potato starches. Indications of holes were discernible in the waxy potato granules, and single, rather large, holes were visible on some normal potato starch granules (Koch & Jane, 2000). In our previous work, acetylated waxy potato starch prepared by reaction with acetic anhydride was chemically gelatinized and the remaining granules were investigated on level of acetylation. Greater proportions of the acetyl groups were present at the periphery than at the core of the granule (Huang, Zhang, Chen, & Li, 2010).

In contrast to the numerous studies on the normal potato starch, the property and morphology of waxy potato starch are still to a great extent unknown. To understand the contribution of granule inner portion to the pasting property of starch, native waxy and

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normal potato starches and their acetylated starch samples were subjected to chemical surface gelatinization to obtain remaining granules. The original and remaining granules were analyzed by rapid visco analyzer (RVA) for their pasting behavior and by SEM and atomic force microscopy (AFM) for their surface morphology.

2. Materials and methods

2.1. Materials

One waxy and two normal potato starch samples were used as starting materials. Waxy potato starch (WPS, amylose-free potato starch) and one of the normal potato starch (NPS-1) were kindly supplied by AVEBE Food Innovation Centre (Veendam, The Netherlands). The other NPS (NPS-2) was a product from Xin Tian Yuan Group (Yulin, China). Amylose contents of NPS-1 and NPS-2 were 26.1% and 26.0%, respectively. Acetylated (Ac) starch samples were prepared in granular form by reaction of starch in aqueous suspension with acetic anhydride as described previously (Huang, Schols, Jin, Sulmann, & Voragen, 2007a). Degrees of substitution (DS) were 0.051, 0.059, and 0.055 for WPS, NPS-1 and NPS-2, respectively. Chemicals were all analytical grade.

2.2. Fractionation and chemical surface gelatinization of granules

Waxy and normal, native and acetylated potato starch samples were fractionated according to granules size as described in a previous paper (Huang et al., 2007a) with some modifications. Dry sieving, instead of wet sieving, was conducted by using two test sieves with pore size of 50 μm and 30 μm, instead of 32 μm and 20 μm. Each starch samples was separated into three fractions: larger than 50 μm, 30–50 μm, and smaller than 30 μm. The starch sample of a homogeneous granular size (30–50 μm) was selected to achieve a uniform chemical gelatinization of starch granules from the surface. Chemical surface gelatinization of waxy and normal, native and acetylated potato starch granules was conducted according to the method of Jane and Shen (1993), and Huang et al. (2010), except that a lower concentration of $CaCl_2$ was used (3.8 mol/L instead of 4 mol/L).

2.3. Particle size distribution, amylose content, and degree of substitution (DS)

Particle size distribution was measured in water with a Laser Particle Size Analyzer (BT-9300Z, Bettersize Instruments Ltd., Dandong, China), the data were processed and specific surface area was obtained by using the software. The apparent amylose content was determined by colorimetric method as described by Duan, Donner, Liu, Smith, and Ravenelle (2012). The DS value was determined using the titration method according to Huang et al. (2007a).

2.4. Rapid visco analyzer (RVA)

The pasting behaviors of the starch samples were measured using a RVA (RVA-TecMaster, Newport Scientific Pty. Ltd., Warriewood, NSW, Australia) in a defined 13 min program: 28 g of 5% (w/w, db) starch suspensions were stirred with a paddle speed of 960 rpm for 10 s to mix and then 160 rpm for 50 s at 50 °C, heated from 50 °C to 95 °C in 3.7 min, held at 95 °C for 2.5 min, cooled to 50 °C in 3.8 min, and held at 50 °C for 2.0 min. The data were processed and obtained by using Thermocline for Windows Version 3.08 (Australia) software.

2.5. Scanning electron microscopy (SEM)

Scanning electron micrographs were obtained with a scanning electron microscope (VEGA III LMH, TESCAN, Czech). Starch samples were applied on a metal stub, and the starch was coated with gold–palladium (60:40).

2.6. Atomic force microscopy (AFM)

Starch was dispersed in the ethanol to form suspension. And about 20 μL suspension is deposited on the freshly cleaved mica and allowing it to dry in air and imaging immediately. The Nanonave E-Sweep AFM (SEIKO Instruments, Chiba City, Chiba, Japan) was used for experiments. Imaging was performed in the tapping mode with silicon probes with spring constants of 40 N/m. Scan areas were 2000 nm × 2000 nm, with scan frequencies 1.7 Hz.

3. Results and discussion

3.1. Chemical gelatinization of native and acetylated waxy potato starch granules

One waxy potato starch (WPS) and two normal potato starches (NPS-1 and NPS-2) and their acetylated (Ac) starch samples were subjected to chemical surface gelatinization to obtain remaining granules. During the $CaCl_2$ (3.8 mol/L) treatment at room temperature, the morphological changes of the granules were observed with polarized light microscope. The calcium ion interacts with the hydroxyl groups of starch molecules, releasing heat that melts nearby starch crystalline regions (Pan & Jane, 2000). Waxy and normal, native and acetylated potato starch granules were all gelatinized beginning at the periphery. It is possible to limit the gelatinization of granules on the surface since the slow penetration of the highly viscous salt solution into starch granules (Pan & Jane, 2000). The layer of gelatinized starch developed at the periphery of the granules resembled a ring for waxy potato starch and a crescent for two normal potato starches (figures not shown) for both native and acetylated samples, the same phenomena were found previously for acetylated waxy and normal potato starches (Huang et al., 2010). These appearances of the gelatinized layers were similar between native and acetylated ones for the same starch. The phenomena were due to evenly attack of $CaCl_2$ solution on both sides of waxy potato starch granule while concentrated attack of $CaCl_2$ solution on one side of normal potato starch granule, and were in accordance with those for acetylated waxy and normal potato starches as shown previously (Huang et al., 2010).

Waxy potato starch granules were chemically gelatinized faster than normal potato starch granules, as reported for native starches by Koch and Jane (2000) and for acetylated starches by Huang et al. (2010). In addition, acetylated granules were chemically gelatinized faster than native granules for the same starch. The introduction of acetyl groups weakens starch molecule interactions in the granules (Taggart, 2004). Therefore, the time required for complete gelatinization varied among waxy and normal, native and acetylated potato starch samples. Thus the six potato starch samples were treated with $CaCl_2$ solution for various times to achieve similar degrees of surface gelatinization (Table 1). The remaining granules were around 70% (w/w) of original granules, and preserved granular structure and polarization cross. The results provided another indication of the spatial structure diversity between waxy and normal potato starch granules in addition to the findings based on acetylated samples (Huang et al., 2010).

3.2. Particle size distribution, amylose content, and degree of substitution

Mean particle sizes (D50) of native and acetylated, original and remaining granules were as follows: NPS-1 > WPS > NPS-2 (Table 2). Axial diameters of 12–72 μm for waxy potato starch (McPherson & Jane, 1999) and 5.5–72.2 μm for normal potato starch (Chen,

Table 1
Degrees of starch chemical gelatinization of waxy and normal potato starch granules after partially gelatinization.

Starch code[a]	Treatment with 3.8 mol/L $CaCl_2$ (min)	Degree of chemical gelatinization (w/w, %)[b]	Amount of remaining granules (w/w, %)[b]
WPS	13	28	72
WPS-Ac	12	33	67
NPS-1	18	25	75
NPS-1-Ac	16	27	73
NPS-2	28	32	68
NPS-2-Ac	20	24	76

[a] WPS, waxy potato starch (AVEBE, the Netherlands); NPS-1, normal potato starch (AVEBE, the Netherlands); NPS-2, normal potato starch (Xin Tian Yuan, China); Ac, acetylated.
[b] Values are means of triplicate and based on dry matter.

Schols, & Voragen, 2003a) have been reported. Compared to the original granules, the mean particle size of the remaining granules was slightly smaller, while the specific surface area showed similar levels. Specific surface area was found to have impact on reaction efficiency when the rapidly reacting reagents (phosphoryl chloride and acetic anhydride) were used, but not for the slowly reacting reagents (propylene oxide analog and vinyl acetate) which had time to penetrate deeply into granule before reacting (Gray & BeMiller, 2004; Huang, Schols, Jin, Sulmann, & Voragen, 2007b; Huber & BeMiller, 2001).

Apparent amylose contents, determined by colorimetric method, were 26.5% and 26.7% for the remaining granules (RG) of NPS-1 and NPS-2, respectively, almost the same levels as found for the corresponding original granules (OG). In contrast, Jane and Shen (1993) analyzed the remaining granules of normal potato starch after chemical gelatinization, and found the amylose content (18.8%) was lower than that of original granules (20.3%). The degree of chemical gelatinization was much lower in our study, ~30% vs. 80% (w/w), which may be the explanation of our different findings.

Degrees of substitution (DS) were 0.047, 0.027, and 0.046 for the remaining granules of WPS, NPS-1 and NPS-2, respectively, lower than those for the original granules. The distribution of acetyl groups within the granule is influenced by the architecture of starch granules. Greater proportions of the acetyl groups were found to be present at the periphery than at the core of the granule, since acetic anhydride reacted rapidly before penetrating and permeating throughout the granule (Huang et al., 2010). Higher reaction efficiency with the hydroxyl groups of the glucosyl residues at the periphery of granule confirmed that acetylation started at the periphery for both waxy and normal potato starch granules, and the acetyl groups were distributed unevenly within starch granule as found previously (Huang et al., 2007b, 2010).

3.3. Pasting properties of remaining granules

3.3.1. Pasting profiles of original and remaining granules

Pasting profiles of waxy and normal, native and acetylated potato starch samples determined by rapid visco analyzer (RVA) are shown in Fig. 1. For native original granules (N-OG), waxy potato starch (WPS) had a sharp peak and jagged pasting profile. This was the result of enormous swelling when cooked in water and a rapid dispersion when swollen to the largest extent (highly stringy pastes) of the granules. The two normal potato starches both showed broader peaks and smoother pasting profiles than waxy potato starch. NPS-1 had a narrow and high peak, while NPS-2 showed a broad and low peak with a front shoulder. McPherson and Jane (1999) demonstrated similar pasting profiles of waxy and normal potato starches as what we found for WPS and NPS-1; while Wickramasinghe, Blennow, and Noda (2009), and Chen, Schols, and Voragen (2003b) showed similar pasting peak of normal potato starch as what we found for NPS-2. The pasting profiles gave evidence of the spatial structure diversity between waxy and normal potato starch granules, as well as variability of normal potato starch granules themselves.

For acetylated original granules (Ac-OG), WPS and NPS-1 resembled native ones in hot-paste viscosity patterns, however, NPS-2 showed a broader and higher peak without shoulder as compared to native one.

Remaining granules (RG) of native WPS showed similar pasting behavior to its original granules, so did acetylated WPS samples, while remaining granules of NPS-1 and NPS-2 behaved obviously different from their original granules. Interestingly, the pasting profile of NPS-1 remaining granules was similar to that of NPS-2 original granules for native starch; furthermore, remaining granules of acetylated NPS-1 and acetylated NPS-2 showed kindred pasting patterns. The results demonstrated that WPS and NPS varied in granule architecture. The periphery and core of WPS starch granules had similar structure, but the periphery and core of NPS granules had different structure. There was a great possibility that

Table 2
Particle size and pasting property of original and remaining granules from native and acetylated waxy and normal potato starches.

Starch code[a]	Particle size		Pasting property (RVA)						
	Mean particle size (D50, μm)	Specific surface area (m^2/g)	Peak viscosity (cP)	Trough viscosity (cP)	Breakdown[b] (cP)	Final viscosity (cP)	Setback[c] (cP)	Peak time (min)	Pasting temperature (°C)
WPS									
N-OG	56.6	0.08	3570	1196	2374	1573	377	3.3	71.9
N-RG	52.4	0.09	2859	1177	1682	1315	138	3.5	72.0
Ac-OG	53.2	0.09	3508	1166	2342	1762	596	3.1	68.0
Ac-RG	49.9	0.09	2866	1341	1525	1756	415	3.3	68.6
NPS-1									
N-OG	61.3	0.08	3807	1675	2132	1970	295	4.1	69.5
N-RG	56.3	0.08	2092	1435	657	1812	377	5.2	68.8
Ac-OG	60.6	0.08	3604	1560	2044	1961	401	3.1	64.5
Ac-RG	55.8	0.08	1289	1073	216	1761	688	4.0	66.2
NPS-2									
N-OG	45.6	0.08	2173	1745	428	2144	399	5.9	71.2
N-RG	44.4	0.08	1560	1490	70	2049	559	6.1	70.4
Ac-OG	52.8	0.07	2539	1746	793	2144	398	4.5	67.8
Ac-RG	44.1	0.08	1189	1071	118	1823	752	5.1	67.1

[a] See Table 1 for an explanation of WPS, NPS-1, NPS-2, and Ac; OG, original granules; RG, remaining granules obtained after treatment with 3.8 mol/L $CaCl_2$ solution.
[b] Breakdown = peak viscosity − trough viscosity.
[c] Setback = final viscosity − trough viscosity.

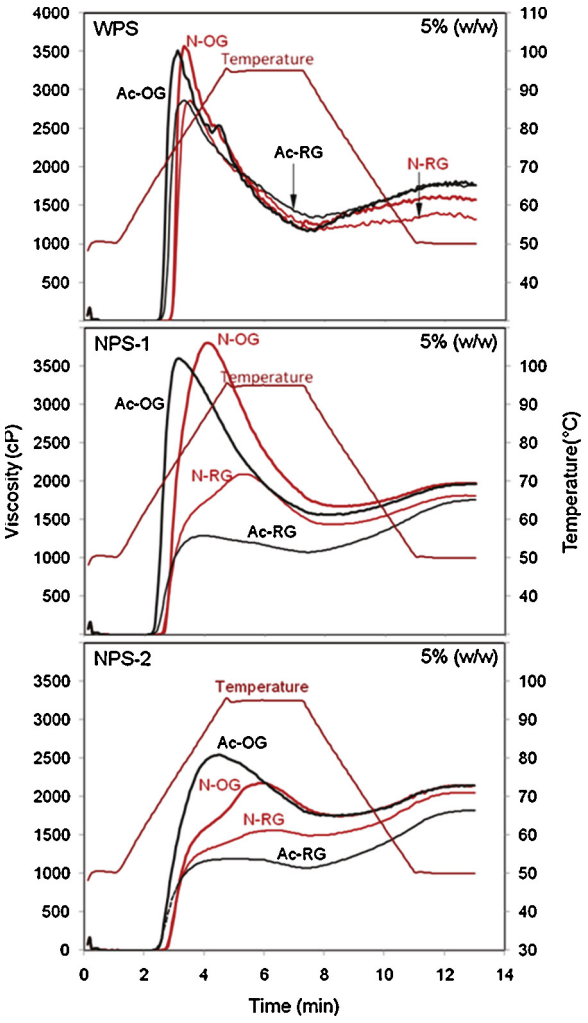

Fig. 1. RVA pasting curves of original and remaining granules from waxy and normal potato starches. RVA: rapid visco analyzer. cP: centipoises. WPS, waxy potato starch (AVEBE, the Netherlands); NPS-1, normal potato starch (AVEBE, the Netherlands); NPS-2, normal potato starch (Xin Tian Yuan, China); OG, original granules; RG, remaining granules obtained after treatment with 3.8 mol/L $CaCl_2$ solution; Ac, acetylated.

NPS-1 and NPS-2 differed in the periphery but not in the core of starch granules.

3.3.2. *Pasting parameters of original granules*

Table 2 shows RVA pasting parameters of tested starch samples. For native original granules, peak viscosity of WPS was slightly lower than that of NPS-1, and much higher than that of NPS-2. The differences among WPS, NPS-1 and NPS-2 were attributed to amylose, chain length of amylopectin, phosphorous content, as well as granule size. McPherson and Jane (1999) reported that normal potato starch displayed a larger peak viscosity than waxy potato starch, and attributed the difference to amylose, fewer long branch chains and less phosphate of waxy potato starch. Smaller granule size, lower amylose and phosphate content, higher branching of amylopectin have been associated with lower values of peak viscosity for potato starch (Noda et al., 2005; Shewmaker et al., 1994). Wickramasinghe et al. (2009) found that negative effect of amylose on peak viscosity (Zaidul et al., 2007) were much weaker than positive effects of starch phosphate and long chains of amylopectin. In addition, a very strong correlation of peak viscosity to phosphorus content was demonstrated by Hemar et al. (2007), Karim et al. (2007) and Noda et al. (2004).

Our two normal potato starch samples do not have much variation in amylose content, thus it was predicted that granule size, phosphorous content, and branching in amylopectin had larger impact on peak viscosity in our case. All these findings together lead to the conclusion that it is dangerous to predict pasting peak solely from the amylose content for potato starch, which is in contrast to most cereal starches.

For the acetylated starches, peak viscosity remained similar for WPS, slightly decreased for NPS-1 and increased for NPS-2 as compared with those of their native counterparts. The results suggested that waxy potato starch was more stable in peak viscosity after acetylation than normal potato starch. Contradicting results were reported by others for normal potato starch after acetylation: decrease in peak viscosity was observed by Chen, Schols, and Voragen (2003c), while increase in peak viscosity was mentioned by Gunaratne and Corke (2007, 2008). Acetylation decreased pasting temperatures in all starch samples as found previously (Chen et al., 2003c; Gunaratne & Corke, 2007, 2008).

3.3.3. *Pasting parameters of remaining granules*

Though all the remaining granules showed lower peak viscosity than the corresponding original granules, no matter waxy or normal, native or acetylated potato starch, the contribution of waxy potato starch granule's inner portion to the peak viscosity was significant more than that of normal potato starch. This may be explained partly by the smaller granule size of remaining granules, but more evidently by the considerable less heterogeneity within waxy potato starch granule than within normal potato starch granules. The apparent lower peak viscosity of remaining granules indicated less organized central region of normal potato starch granule. Inside normal starch granules, the starch molecular arrangement is different from the outer layer (Fannon, Gray, Gunawan, Huber, & BeMiller, 2004; Ziegler, Creek, & Runt, 2005). There was a layer of highly ordered starch molecules near the periphery of granules for normal potato starch (Gray & BeMiller, 2004; Huber & BeMiller, 2001). Furthermore, the assembly of macromolecules was not uniform in granule (Chung & Lai, 2006), including size of amylose, structure of amylopectin, and phosphate content (Jane & Shen, 1993).

In contrast to the peak viscosities, the final viscosities of all tested samples were comparatively close to each other. These phenomena probably due to the fact that the peak viscosity was more related to the size and architectural features of starch granules, while the final viscosity was more relied on the size and structure of starch molecules. Thus, in a comparison of remarkable heterogeneity in granule architecture, WPS, NPS-1 and NPS-2 had less difference in molecular structure.

Peak time of WPS was less than those of NPS-1 and NPS-2. Moreover, native and acetylated, original and remaining granules of WPS showed basically the same peak time, while the counterparts of NPS showed difference in peak time from each other, owing to easier and faster swelling, more tolerance of acetylation for WPS granules than NPS granules. This was evidence of difference in granule organization between WPS and NPS. The negligible variation in pasting temperature among all tested samples, suggesting that their crystal structures were quite similar, and thus the difference among WPS, NPS-1 and NPS-2 was probably, to a large extent, due to their amorphous regions in granule.

In general, when compared to normal potato starch samples, differences between native and acetylated, original and remaining granules were much smaller for waxy potato starch samples, which could be explained by the assembling from sole amylopectin to granule was more uniform from inner to outer layers for WPS, while the granule assembling of NPS granule had more variability due to the presence of amylose and the diversity was more significant within one granule and among different granules.

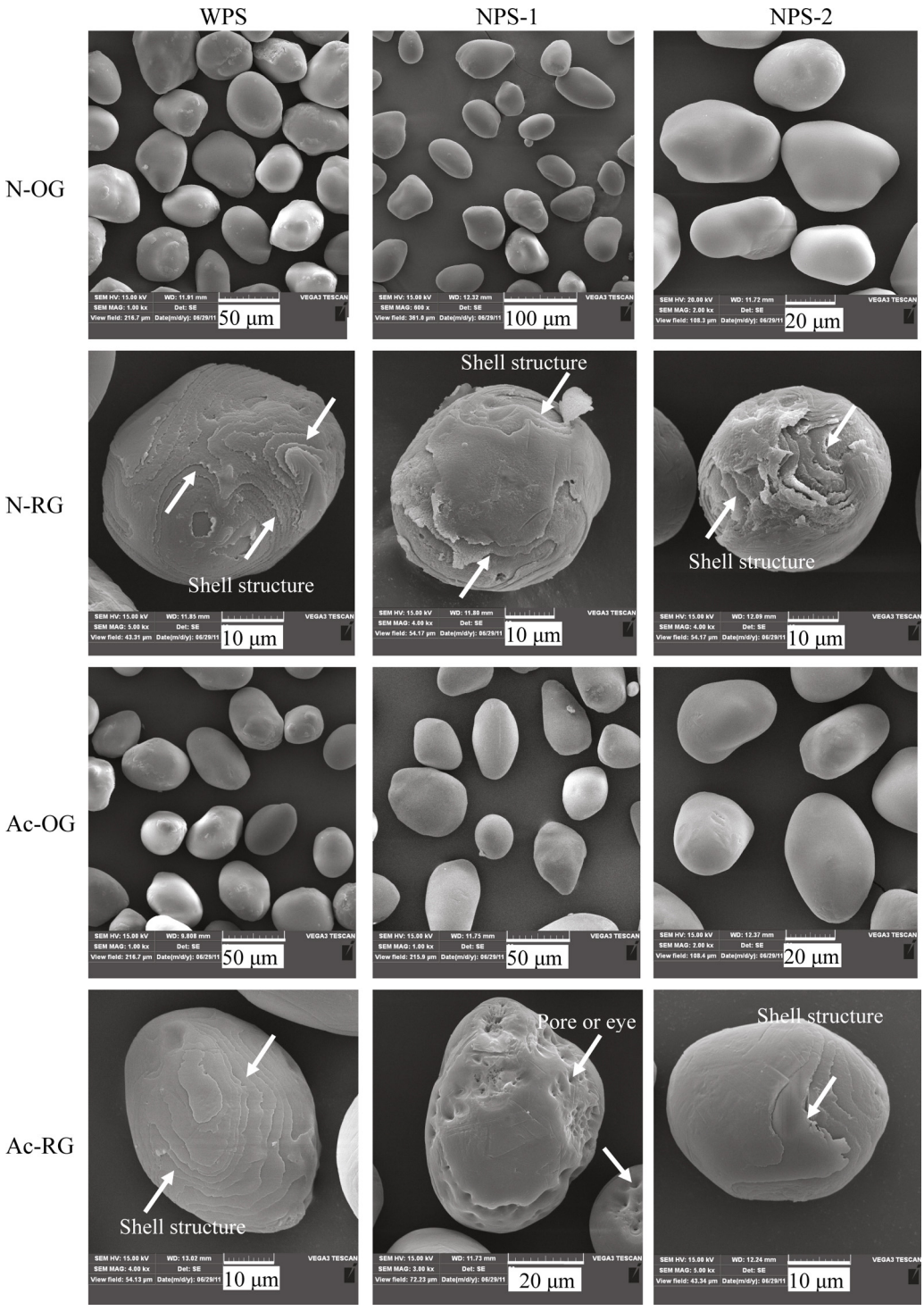

Fig. 2. Scanning electron micrographs (SEM) of original and remaining granules from waxy and normal potato starches. See Fig. 1 for an explanation of starch codes. Arrows indicate shell structure, pores or eyes on the surface of remaining granules.

3.4. Morphology of remaining granules—SEM

The morphology of original and remaining granules was investigated by using scanning electron microscopy (SEM). There was no obvious difference between waxy and normal, native and acetylated potato starches for original granules in shape and surface (Fig. 2). The surface morphology of all remaining granule samples showed that the gelatinized starch at the periphery of the granule was removed adequately. The remaining granule surfaces were uneven and showed a shell structure and pores or eyes for waxy and normal, native and acetylated potato starches. Pan and Jane (2000) also reported a lamella (shell) structure on the surface of maize starch remaining granules obtained from chemical surface gelatinization. Biosynthesis of starch granules takes place primarily in the amyloplast and is initiated at the hilum and the starch granule grows by apposition (Jane, 2009). Starch synthase involved in the synthesis of amylose and amylopectin were entrapped inside the starch granules (Mukerjea, Mukerjea, & Robyt, 2009). The fact that protein content is lower and granule size is larger for potato starch than for other starches (Chen et al., 2003a; Gray & BeMiller,

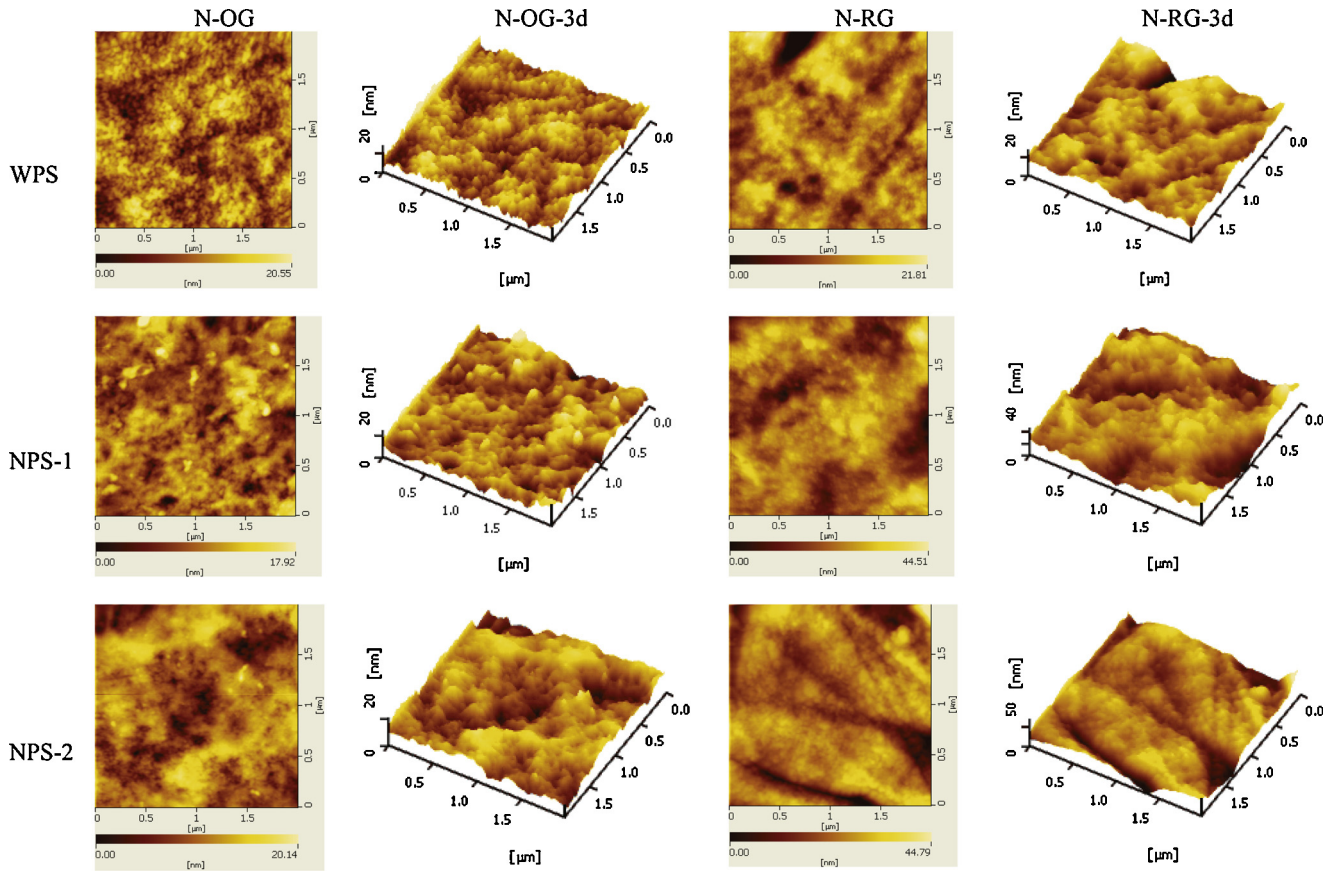

Fig. 3. AFM topography images of surface regions of waxy and normal potato starches original and remaining granules (scan area 2000 nm × 2000 nm, *z* height difference from 17.92 nm to 44.79 nm—representing the difference between the highest and lowest points measured in the scan) AFM: atomic force microscopy. See Fig. 1 for an explanation of starch codes.

2004; Huber & BeMiller, 2001), suggests most starch synthase leave potato granules after action. Thus, it is assumed that the holes or eyes were possibly the channels for the retreat of starch synthase.

The shell structure appeared on the remaining granule surface for waxy potato starch was smoother and thinner than that for normal potato starch, since the surface of waxy potato starch granule was more evenly corroded by the salt solution than that of normal potato starch granule, indicating a more regular structure of shell and a more ordered packing of shell in the granule for waxy potato starch than those for normal potato starches. Our previous findings are slightly different, where acetylated waxy potato starch remaining granule showed rough surface, whereas acetylated normal potato starch remaining granule showed relatively smooth surface (Huang et al., 2010). Variation in the surface morphology of the remaining granules may due to the lower concentration of $CaCl_2$ solution during chemical gelatinization as well as the lower level of the residual gelatinized starch on the surface of remaining granules in this study.

The surface of acetylated samples' remaining granules was smoother than that of native samples' for both waxy and normal potato starches. The presence of acetyl groups accelerates the melting of starch crystalline regions and promotes the mechanical removal of the gelatinized starch at the periphery of the granules.

3.5. Surface morphology of remaining granules—AFM

High resolution imaging of the unembedded starch granule surface has been performed using atomic microscopic microscopy (AFM) technique. AFM images of surface details of the original granules and remaining granules of native waxy (WPS) and normal (NPS-1 and NPS-2) potato starches are shown in Fig. 3. All the granules exhibited a rough surface with many protrusions of ellipsoid and irregular size, and many depressions of different shape and size. These protrusions were believed to be "blocklet" structures with diameters ca. 10–100 nm. Numerous fine particles or blocklets (30–50 nm) organized in larger agglomerates was observed on surface of native potato starch granules based on the AFM images (Park, Xu, & Seetharaman, 2011; Sujka & Jamroz, 2009). Earlier reported blocklet sizes on potato starch granule surfaces, imaged using AFM after partial embedding, was larger (50–300 nm in diameter) (Baldwin, Adler, Davies, & Melia, 1998; Baldwin, Davies, & Melia, 1997), probably due to the influence of embedding material on the images of AFM as mentioned by Ridout, Gunning, Parker, Wilson, and Morris (2002).

The blocklet sizes of waxy potato starch were smaller and more uniform than those of normal potato starch, for both original and remaining granules. Furthermore, the height difference (representing the difference between the highest and lowest points measured in the scan in AFM images, Fig. 3) between original and remaining granules of waxy potato starch was smaller than those of normal potato starches, indicating comparatively smooth surface for waxy potato starch granules, and less variation in surface morphology between its original and remaining granules. This confirmed the results of SEM that less heterogeneity existed between core and periphery structures for waxy potato starch granule as compared to normal potato starch granule.

The blocklet sizes of remaining granules were larger (ca. 40–100 nm in diameter) than those of original granules (ca. 10–30 nm in diameter) for both waxy and normal potato starches. The surface of the remaining granules is more rough than in

case of original ones as observed by SEM. The AFM image of NPS-2 remaining granule revealed scratches on the surface, these were evidence of knife damage during mechanical separation of gelatinized starch.

4. Conclusions

Native and acetylated, original and remaining granules of waxy potato starch had similar RVA pasting profiles, while those of two normal potato starch samples behaved obviously different from each other. Waxy potato starch was more stable in peak viscosity after acetylation than normal potato starch. All remaining granules exhibited lower peak viscosity than the corresponding original granules. Moreover, the contribution of waxy potato starch granule's inner part to the peak viscosity was significant more than those of normal potato starches, suggesting different molecular arrangement within granule between waxy and normal potato starches.

The SEM images of remaining granules showed a shell structure, pores or eyes, and uneven surface for waxy and normal, native and acetylated potato starches. The shell structure appeared on the remaining granule surface for waxy potato starch was smoother and thinner than those for normal potato starches, indicating more regular structure of shell and more ordered packing of shell in the granule for waxy potato starch than those for normal potato starch.

Atomic microscopic microscope (AFM) images of original and remaining granules exhibited the blocklet sizes of waxy potato starch were smaller and more uniform than those of normal potato starch.

In general, results of pasting property and surface morphology were indications of the spatial structure diversity between waxy and normal potato starch granules: waxy potato starch granule was more uniform from inner to outer layers, while the granule assembling of normal potato starch granule had more variability due to the presence of amylose and the diversity was more significant within one granule and among different granules.

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