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# Characterization of Starches from Roots of *Panax ginseng* C.A. Meyer and *Panax notoginseng* (Burk.) F.H. Chen

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**Abstract: Various physicochemical properties were investigated to assess the potential of starch from the extract of crude drugs (C). Starches (S) were prepared from the roots of *Panax ginseng* C.A. Meyer (PG) and *Panax notoginseng* (Burk.) F.H. Chen (PN). C-PGs and C-PNs contained 5.0–20.0 and 2.0–5.6% starch, respectively. Average diameters of S-PG and S-PN granules were 6.3 ± 1.1 and 11.0 ± 0.7 $\mu$m, respectively. S-PGs and S-PNs were classified as $C_B$-type and $C_A$-type, respectively. The S-PG-4 and S-PN-4 showed endothermic curves from 44.2 to 69.5 and 51.2 to 72.5°C, their enthalpy being 8.6 ± 0.4 and 11.7 ± 0.7 J/g, respectively. S-PN granules are suggested to be more stable to both moisture and heat than S-PG granules. P contents of S-PGs and S-PNs were 56.0–64.0 and 67.0–120.0 $\mu$g/g, respectively. Ca contents of S-PGs were 38.0–83.0 $\mu$g/g, and those of S-PNs were 26.0–180.0 $\mu$g/g. The digestibility of raw S-PGs and S-PNs by α-amylase was 82.3 ± 4.8 and 55.0 ± 7.5%, respectively, at 72 h. The main oligosaccharide products from the raw starches (digestibility, S-PG-4: 13.2%; S-PN-4: 20.7%) digested by α-amylase were maltotriose (40.2–40.6%) and maltose (36.4–39.1%) and that from the starches (digestibility, S-PG-4: 17.6%; S-PN-4: 27.9%) digested by glucoamylase was glucose (92.9–98.3%). The digested S-PG-4 and S-PN-4 granules (digestion time, 1 h) were roughly eroded by α-amylase and the starches digested by glucoamylase were well maintained to retain their original forms with a few fine grains on their granular surface. It was suggested that the thermostability of S-PG-4 and S-PN-4 digested by glucoamylase was higher than that of the starches digested by α-amylase.**

**Key words: crude drug starch, physicochemical property, digestibility by α-amylase, digestibility by glucoamylase, oligosaccharide**

The traditional Chinese drug Ginseng, the root of *Panax ginseng* C.A. Meyer (PG) and Sanchi Ginseng, the root of *Panax notoginseng* (Burk.) F.H. Chen (PN), have been used as a peptic digestive, a drug for controlling intestinal function, a tonic and a hemostatic. The granular size distribution, amylose content and blue value of Korean ginseng starch has been reported.[1)] Adsorption of water[2)] and dyes[3)] by crude drug starches of PG and PN have also been investigated.

Crude drug (C) has been utilized as a raw material for extracts and powdered crude drugs. The purpose of this study was to make profitable the use of starch from the extract of the active ingredients of the crude drugs PG and PN. This paper reveals physicochemical properties such as particle size distribution, crystalline structure, gelatinization property, mineral content and digestibility by α-amylase or glucoamylase, which are essential for any application. The physicochemical characteristics of PG and PN starches were examined.

## MATERIALS AND METHODS

***Materials.*** The roots of *Panax ginseng* C.A. Meyer (PG) and *Panax notoginseng* (Burk.) F.H. Chen (PN) were purchased in November 2000 from Fukuda Ryu Co., Ltd. (Osaka, Japan). The PGs were: PG-1 (two-year-old root harvested at Jilin, China in 1999, red ginseng), PG-2 (two-year-old root harvested at Jilin, China in 1999), PG-3 (two-year-old root harvested at Heilongjiang, China in 1999), PG-4 (four-year-old root harvested in Korea in 1997) and PG-5 (six-year-old root harvested in Korea in 1997). The PNs (Wenshan, Yunnan, China, three-year-old root) were: PN-1 (head number (HN) = 20, harvested in 1999. HN implies the classification by the size of tuberous root.), PN-2 (HN = 30, harvested in 1998), PN-3 (HN = 80, harvested in 1998), PN-4 (HN = 120, harvested in 1998), PN-5 (HN = 160, harvested in 1999) and PN-6 (HN = 200, harvested in 1999). Enzymes, α-amylase from *Porcine pancreas* (EC 3.2.1.1; type I A: DFP treated; 790 U/mg protein, 30 mg protein/mL; assay, colorimetric method. One unit will liberate 1.0 mg of maltose from starch in 3 min at pH 6.9 at 20°C) and glucoamylase from *Aspergillus niger* (EC 3.2.1.3; 53 U/mg protein, 13 mg protein/mL; assay, spectrophotometric stop rate determination method. One unit will liberate 1.0 mg of glucose from starch in 3 min at pH 4.5 at 55°C) were purchased from Sigma Chemical Corporation St. Louis, MO, USA. The enzymes were used without further purification and enzyme assay. All other reagents, solvents and oligosaccharide samples were of the highest grade commercially available.

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Abbreviations: PG, root of *Panax ginseng* C.A. Meyer; PN, root of *Panax notoginseng* (Burk.) F.H. Chen; HN, head number; DSC, differential scanning calorimeter; SEM, scanning electron microscope; C, powdered crude drug; S, starch.

***Preparation of powdered crude drugs and measurement of components.*** C was prepared as described in a previous paper.[2] The powdered samples were passed through a 100 mesh screen. Loss on drying of C was measured according to the method of Japanese Pharmacopoeia.[4] Crude fat, crude protein and crude fiber of C were determined by the ethyl ether extraction method,[5] the semi-micro Kjeldahl method[5] and the improved method of Henneberg-Storman,[5] respectively.

***Preparation of starch.*** The starches were prepared, deproteinized and defatted as described previously.[2] Starch content was measured based on the weight of purified starch. The starch was screened by a 400 mesh or finer and kept in a tight container. The PG-4 and PN-4 starches were the same samples used in adsorption experiments.[2,3]

***Measurement of particle size distribution.*** The particle size distribution was measured with a laser diffraction particle size analyzer, SALD-2100 (Shimadzu Seisakusho, Co., Ltd., Kyoto, Japan), after dispersing the starch in a 0.01% neutral detergent (Ekiserin, Kao Corporation, Tokyo, Japan) solution.

***SEM observation.*** Starch was scattered on a double-faced tape stuck on the sample holder. After spattering with gold ion using a cryounit, the sample was observed with an electron probe microanalyzer-8705 (Shimadzu Seisakusho, Co., Ltd., Kyoto, Japan) at 10 kV of acceleration voltage at a magnification of 2000 times.

***X-ray diffraction.*** X-ray diffraction was performed on an X-ray diffractometer equipped with a RINT 2000 wide angle goniometer (Rigaku Denki Co., Tokyo, Japan) on moist starch (water activity, 81%). The conditions for measuring X-ray diffractograms were as follows: anticathode, Cu; impressed voltage, 40 kV; current, 120 mA; scanning range, 4–40°, scanning speed of goniometer, 4 °C/min.

***DSC analysis.*** DSC analysis was performed with a PC-based thermal analyzer, the DSC 2010 (TA Instruments, New Castle, DE, USA). The conditions for measuring DSC were as follows: sample pan, hermetic aluminum pan, 5 mm$\phi$×2.5 mm; standard sample, air. After 30 mg of starch was homogeneously suspended in 75 $\mu$L of distilled water, one drop of the suspension was sealed into the pan. The heating rate was 5°C/min. The digested starch was prepared as follows. After the raw starch was digested by $\alpha$-amylase or glucoamylase for 1 h, amyl alcohol was used for the removal of residual enzyme from the suspension. The starch residue was washed with alcohol and then with ether, and it was dried in a vacuum for 2 days. The sample consists of the water-insoluble residue, because the oligosaccharide products are water-soluble.

***Determination of inorganic elements.*** Starch was decomposed with nitric acid-perchloric acid according to the wet digestion method.[5] The decomposed solution was diluted with ultra-pure water in a volumetric flask. Determinations of P, Mg and Ca were performed with an ICPS-2000 sequential plasma spectrometer, (Shimadzu Seisakusho, Co., Ltd., Kyoto, Japan). Starch was ashed at 500°C for 2 h in a porcelain crucible according to the dry combustion method.[6] The ash was dissolved in a 1 M hydrochloric acid solution. The solution was diluted with ultra-pure water in a volumetric flask. Determination of Na and K were performed with an AA-6800 atomic absorption-flame emission spectrophotometer (Shimadzu Seisakusho, Co., Ltd., Kyoto, Japan).

***Digestibility of raw starch by α-amylase and determination of oligosaccharide products after digestion by α-amylase or glucoamylase.***

The digestibility of raw starch by $\alpha$-amylase or glucoamylase was evaluated according to the method of Fuwa *et al*.[7] Starch granules (50 mg) were digested by $\alpha$-amylase (15 U) at pH 7.2 and 37°C in a 6.7 mM phosphate buffer solution (8.5 mL) containing 10 mM sodium chloride and 10 mM calcium acetate. Starch granules (50 mg) were digested by glucoamylase (15 U) at pH 4.5 and 37°C in an acetic acid-sodium acetate buffer solution (8.5 mL). The amounts of reducing sugars formed by the enzymatic reaction up to 72 h were determined by the Somogyi method.[8] Amounts of oligosaccharide products after digestion (1 h) by $\alpha$-amylase and glucoamylase were determined by the PMP (1-phenyl-3-methyl-5-pyrazolone) derivatives method of Honda *et al*.[9]

Crude drugs of the same producing district and grade as described for PG-4 and PN-4 have been mainly utilized in our company as a raw material for healthy food. Since the susceptibility to enzyme of raw starch is essential for the application of crude drug to a healthy food, the PG-4 and PN-4 starches were picked up. Since it is presumed that starch is digested by $\alpha$-amylase in the small intestine for 1 h, the amounts of oligosaccharide products after 1 h digestion *in vitro* were determined.

## RESULTS AND DISCUSSION

***Components of powdered crude drugs.***

The typical components of Cs were examined (Table 1). C-PGs contained more fat (1.3%), protein (13.2%), fiber (4.3%) and starch (10.6±6.1%) than C-PNs (0.3, 7.4, 3.3 and 4.0±1.4% of C-PNs, respectively). Protein was the most common component, followed by starch. Starch contents of C-PGs and C-PNs were 5.0–20.0 and 2.0–5.6%, respectively. Kim *et al*.[1] reported that the starch content of Korean ginseng was 9.62% for one-year-old root, 10.35% for two-year-old root, 15.50% for three-year-old root, 17.05% for four-year-old root and 18.32% for five-year-old root. Starch content of C-PGs, however, did not always increase with the age of the root, due to different areas of their productions (Table 1). And the difference in starch content of PGs by each production area could not be explained on the basis of the results of Table 1. Starch levels in C-PNs of three-year-old root were approximately constant.

***Physicochemical properties of starch.***

Particle size distribution is shown in Fig. 1. Particle sizes of PG and PN starch granules were distributed in the ranges of 2 to 20 and 2 to 50 $\mu$m, respectively. The average diameter of PG starches was 6.3±1.0 $\mu$m. The average diameter of PN starches was 10.9±0.7 $\mu$m. However, except for the average diameter (9.7±0.2 $\mu$m) of PN-3 starch, that of five PN starches was 10.9±0.2–11.8

**Table 1.** Components of powdered crude drugs PG and PN.

| Powdered crude drug sample | Loss on drying (%) | Crude fat (%) | Crude protein (%) | Crude fiber (%) | Starch (%) |
|---|---|---|---|---|---|
| PG-1 | 8.1 | 1.3 | 12.6 | 4.9 | 5.0 |
| PG-2 | 7.7 | 1.4 | 12.9 | 3.6 | 20.0 |
| PG-3 | 8.3 | 1.2 | 13.3 | 4.3 | 10.0 |
| PG-4 | 8.3 | 1.5 | 14.1 | 4.6 | 5.6 |
| PG-5 | 8.5 | 1.3 | 13.0 | 4.1 | 12.6 |
| Mean±SD | 8.0±0.5 | 1.3±0.1 | 13.2±0.6 | 4.3±0.5 | 10.6±6.1 |
| PN-1 | 8.6 | 0.2 | 7.9 | 3.0 | 5.2 |
| PN-2 | 9.1 | 0.2 | 7.9 | 3.0 | 2.9 |
| PN-3 | 9.7 | 0.3 | 6.0 | 3.1 | 5.6 |
| PN-4 | 8.8 | 0.4 | 6.9 | 3.1 | 2.0 |
| PN-5 | 11.2 | 0.4 | 7.7 | 4.0 | 4.4 |
| PN-6 | 9.9 | 0.3 | 7.9 | 3.7 | 4.1 |
| Mean±SD | 9.6±1.0* | 0.3±0.1* | 7.4±0.8* | 3.3±0.4* | 4.0±1.4 |

PG, root of *Panax ginseng* C.A. Meyer; PN, root of *Panax notoginseng* (Burk.) F.H. Chen; PG-1, Jilin China, red ginseng, two-year-old root; PG-2, Jilin China, two-year-old root; PG-3, Heilongjiang China, two-year-old root; PG-4, Korea, four-year-old root; PG-5, Korea, six-year-old root; PN-1–PN-6, Wenshan Yunnan China, three-year-old root; PN-1, head number (HN)=20 (26.00±3.12 g); PN-2, HN=30 (16.05±0.66 g); PN-3, HN=80 (6.33±1.03 g); PN-4, HN=120 (4.09±0.47 g); PN-5, HN=160 (3.26±0.33 g); PN-6, HN=200 (2.67±0.34 g). The size of tuberous root is classified by head number. The number in the parenthesis indicates the mean weight per root of PN ($n$=20).[13] Mean±SD. Significant difference between PG and PN with the paired $t$-test ($^*p<0.05$).

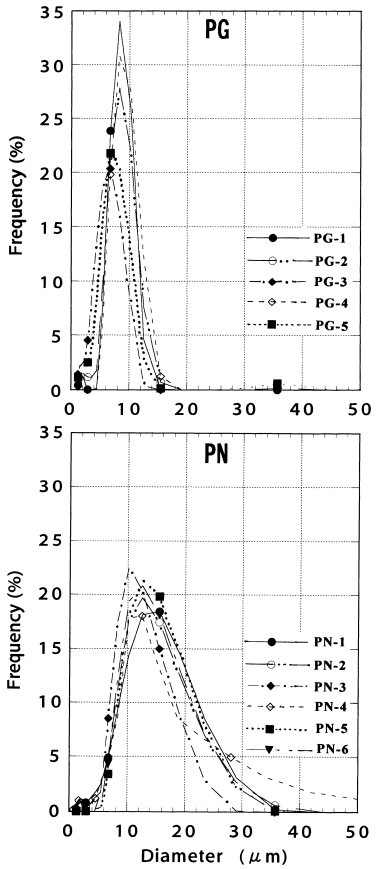


**Fig. 1.** Particle size distributions of PG and PN starch granules.

For abbreviations see Table 1. A significant difference in average diameter (6.3±1.1 μm) between PG starch granules and (11.0±0.7 μm) PN starch granules was obtained with the paired $t$-test ($p<0.05$).

±0.2 μm. From observation by SEM (Fig. 2), the granular sizes of the S-PG-4 and S-PN-4 were 3–9 and 4–14 μm, respectively. The granular sizes measured by two different methods almost agreed. The S-PG-4 and S-PN-4 granules displayed irregular shapes, that is, angulate, wrinkled, oval and spherical (Fig. 2).

X-ray diffractograms were measured to elucidate the crystalline structure (Fig. 3). Since PG starch had peak 3 with a small shoulder (3b), peak 4 with a sharp one and peak 6 with two peaks of 6a and 6b, it was classified as type $C_B$, similar to B-type.[10] PN starches had peak 3 with no shoulder, peak 4 with two peaks of 4a and 4b and peak 6 with no shoulder, being classified as type $C_A$, similar to A-type.[10] Since A-type is more stable than B-type in crystalline structure,[11] PN starch granules are suggested to be more stable to both moisture and heat than PG starch granules.

Gelatinization temperature and enthalpy were measured to elucidate the thermal properties of PG and PN starches (Table 2). Onset, peak and final temperatures of the endothermic curve of undigested PG-4 starch were 44.2±0.9, 50.8±0.4 and 69.5±0.4°C, respectively. Onset, peak and final temperatures of undigested PN-4 starch were 51.2±0.2, 57.2±0.4 and 72.5±0.7°C, respectively. The enthalpy of their PG-4 and PN-4 starches was 8.6±0.4 and 11.7±0.7 J/g, respectively. The degree of susceptibility to swelling of starch corresponds well to that of unstable crystallite, the $C_B$-type being more unstable to moisture and heat than the $C_A$-type.[11] The broader endothermic curve, lower gelatinization temperature and smaller $\Delta H$ value indicate that PG-4 starch is swollen[12] with more water than the PN-4 starch.

Mineral contents were measured to compare the two

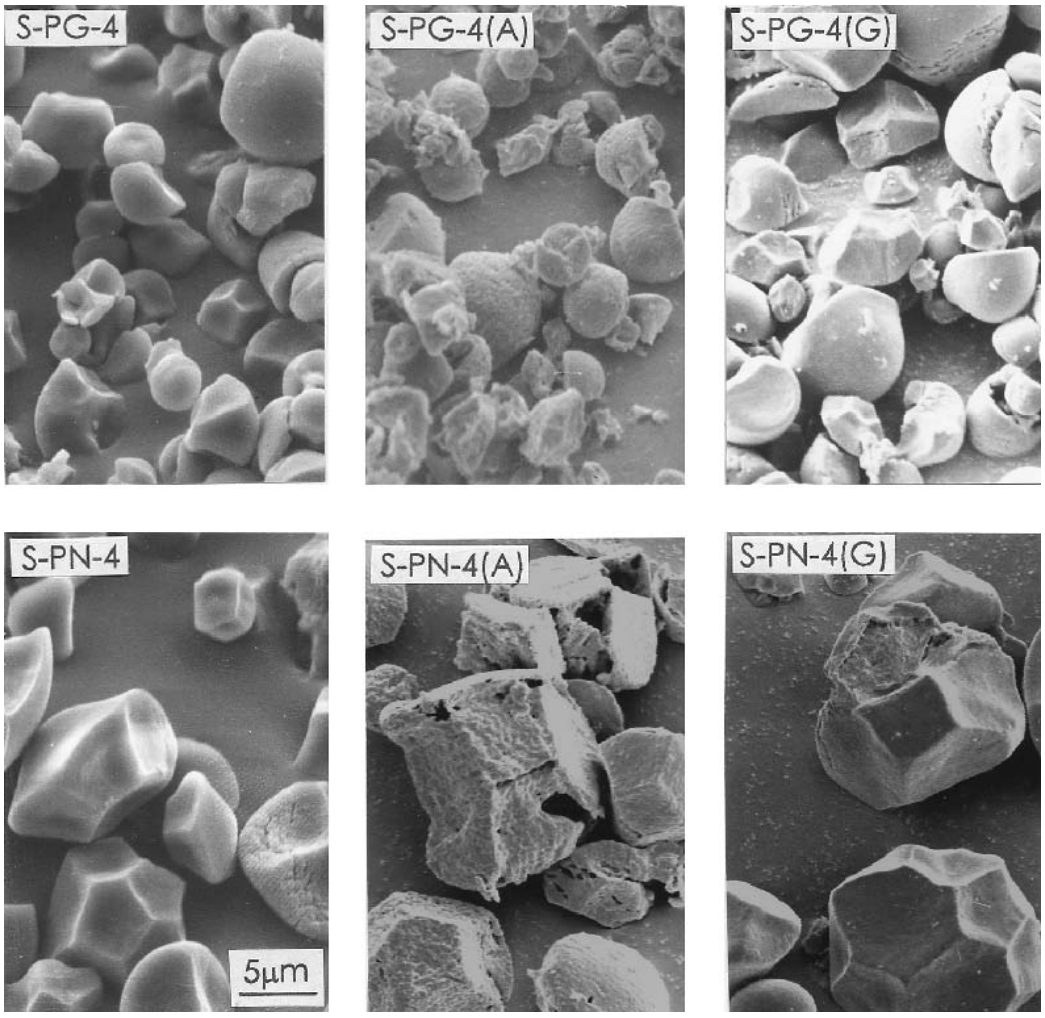


**Fig. 2.** Scanning electron micrographs of PG-4 and PN-4 starches and their starches digested by $\alpha$-amylase or glucoamylase for 1 h.

S-PG-4, undigested PG-4 starch; S-PG-4(A), PG-4 starch digested by $\alpha$-amylase for 1 h; S-PG-4(G), PG-4 starch digested by glucoamylase for 1 h; S-PN-4, undigested PN-4 starch; S-PN-4(A), PN-4 starch digested by $\alpha$-amylase for 1 h; S-PN-4(G), PN-4 starch digested by glucoamylase for 1 h.

species of starches in terms of chemical properties (Table 3). P contents of PG starches were 56.0–64.0 $\mu$g/g and the variation was small. P contents of PN starches, however, varied in the range of 67.0 to 120 $\mu$g/g. Ca contents of PG starches were in the range of 38.0 to 83.0 $\mu$g/g, and those of PN starches varied widely from 26.0 to 180.0 $\mu$g/g. K, Na and Mg contents of PN starches were 3 to 4 times as high as those of PG starches.

The root size of PN has been classified by the head number.[13] Positive correlations were observed ($p<0.01$) between P or Ca content (Table 3) and weight per test sample (Table 1).[13] The results, therefore, indicate that P and Ca may increase while the PN root grows in weight.

***Digestibility of raw starch by α-amylase, and thermal properties of digested starch and composition of oligosaccharides after digestion by α-amylase or glucoamylase.***

The digestibility of PG and PN starches by $\alpha$-amylase was measured at 37°C to estimate the susceptibility to $\alpha$-amylase of the raw starch contained in granules, pills or tablets[2] prepared from both powdered crude drug and its extract solution (Fig. 4). The digestibility (%) of PG starches increased uniformly up to 60% and then approached 74–86% (82.3±5.0%) at 72 h. On the other hand, the digestibility of PN starches increased rapidly up to approximately 40% and then approached a limit of 45–65% (55.0±7.5%) at 72 h. The result that the digestibility of PG starch was higher than that of PN starch (Fig. 4) and the results of average diameter (Fig. 1) and $\Delta H$ of undigested starch (Table 2) agreed with the finding[14] that digestibility (%) by amylase was negatively correlated with average granular size and $\Delta H$. The results, therefore, suggest that PN starch has a more stable structure to both moisture and heat than PG starch. The digestibility of PG and PN starches was very high as compared with that of raw potato starch of which 7% was digested at 24 h, as reported by Fuwa *et al*.[7] The digestibility (75.0±6.0% at 24 h) of PG starches was the same as that (75%[15] at 24 h) of kudzu starch.

The suspension of starch digested by an enzyme consists of water-insoluble residue and water-soluble oligosaccharides.[7] Thermal properties of the water-insoluble residue after attack by $\alpha$-amylase were measured (Table 2). Two peaks of the endothermic curve of the digested PG-4 starch appeared at a higher temperature and its enthalpy decreased to 1/5, compared to PG-4 starch. The endothermic curve of the digested PN-4 starch shifted slightly to a higher temperature and the enthalpy decreased to 1/2, compared to PN-4 starch. The results sug-

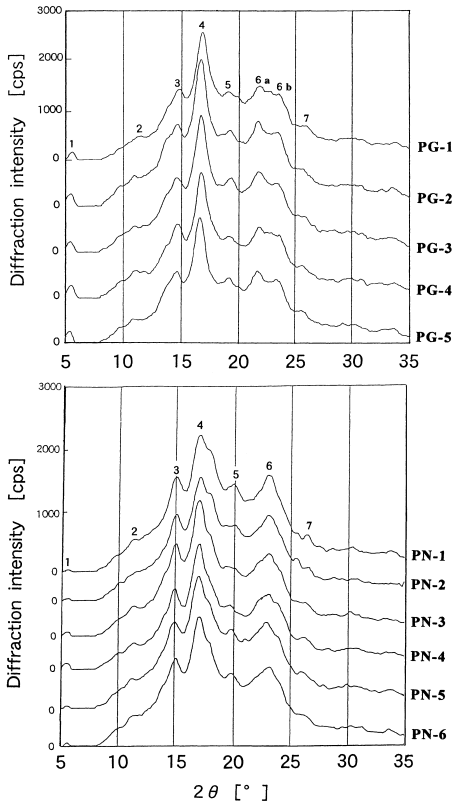


**Fig. 3.** X-ray diffractograms of PG and PN starches.

For abbreviations see Table 1. The numbering is based on the reference.[10]

gest that the digested PN-4 and PG-4 starch granules were made more porous by $\alpha$-amylase, like the digested granules of katakuri starch[15] and loquat seed starch.[16]

The composition of oligosaccharide products by $\alpha$-amylase was measured (Table 4). Total oligosaccharides from the PG-4 starch were approximately three times as high as those from PN-4 starch. Maltotriose was the most abundant (40.2–40.6%), followed by maltose (36.4–39.1%), glucose, isomaltose and maltotetraose through maltoheptaose the third most abundant (20.1–23.3%). The fact that maltotriose and maltose accounted for 80% of all products could be explained by the high frequency of attack by $\alpha$-amylase of the various $\alpha$-1→4 glycosidic bonds, mainly producing maltose and maltotriose.[17]

**Table 2.** Gelatinization properties of PG-4 and PN-4 starches and their starches digested by $\alpha$-amylase or glucoamylase.

| Starch sample | $T_o$ (°C) | $T_p$ (°C) | $T_f$ (°C) | $\Delta H$ (J/g) |
|---|---|---|---|---|
| Undigested starch | | | | |
| PG-4 | 44.2±0.9 | 50.8±0.4 | 69.5±0.4 | 8.6±0.4 |
| PN-4 | 51.2±0.2 | 57.2±0.4 | 72.4±0.7 | 11.7±0.7 |
| Starch digested by $\alpha$-amylase* | | | | |
| PG-4 | 51.3±0.6 | 55.2±0.6 | 61.7±0.4 | 0.8±0.3 |
| | 64.3±0.7 | 71.2±0.8 | 76.6±0.5 | 1.0±0.3 |
| PN-4 | 51.2±0.3 | 58.1±0.3 | 74.1±0.2 | 6.4±0.1 |
| Starch digested by glucoamylase** | | | | |
| PG-4 | 62.5±0.2 | 66.5±0.1 | 72.0±0.2 | 8.8±0.9 |
| PN-4 | 63.8±0.1 | 66.1±0.2 | 74.7±0.4 | 2.8±0.2 |

$T_o$ (°C), onset temp.; $T_p$ (°C), peak temp.; $T_f$ (°C), final temp.; $\Delta H$ (J/g), enthalpy. Values are means±SD ($n=3$). *Starch was digested by $\alpha$-amylase for 1 h at 37°C (digestibility: PG-4 starch, 13.2%; PN-4 starch, 20.7%). **Starch was digested by glucoamylase for 1 h at 37°C (digestibility: PG-4 starch, 17.6%; PN-4 starch, 27.9%).

Thermal properties of the water-insoluble residue after attack by glucoamylase were measured (Table 2). The endothermic curves of the digested PG-4 and PN-4 starches appeared at a higher temperature, compared to those of the PG-4 and PN-4 starches. The temperature range of the endothermic curves after digestion by glucoamylase (about 10°C) was narrower than that after digestion by $\alpha$-amylase (21–25°C).

From observations by SEM (Fig. 2), it was found that the interior and exterior of the digested PG-4 and PN-4 starch granules were roughly eroded by $\alpha$-amylase and that the starches digested by glucoamylase were well maintained to retain their original forms with a few fine grains on their granular surface. The results of DSC and SEM suggest that the thermostability of the starches digested by glucoamylase was higher than that of the starches digested by $\alpha$-amylase, and that the difference in thermostability was attributable to the large difference in

**Table 3.** Mineral contents of PG and PN starches.

| Starch sample | Mineral content (μg/g) | | | | |
|---|---|---|---|---|---|
| | P | K | Na | Ca | Mg |
| PG-1 | 56.0 | 2.3 | 9.1 | 83.0 | 9.0 |
| PG-2 | 61.0 | 1.4 | 3.5 | 38.0 | 7.0 |
| PG-3 | 57.0 | 2.3 | 5.0 | 42.0 | 6.9 |
| PG-4 | 60.0 | 13.0 | 16.0 | 42.0 | 6.3 |
| PG-5 | 64.0 | 2.1 | 4.1 | 48.0 | 9.7 |
| Mean±SD | 59.6±3.2 | 4.2±4.9 | 7.5±5.2 | 50.6±18.5 | 7.8±1.5 |
| PN-1 | 120.0 | 9.1 | 11.0 | 180.0 | 15.0 |
| PN-2 | 100.0 | 7.9 | 23.0 | 69.0 | 29.0 |
| PN-3 | 91.0 | 14.0 | 9.0 | 39.0 | 18.0 |
| PN-4 | 67.0 | 23.0 | 24.0 | 35.0 | 25.0 |
| PN-5 | 81.0 | 3.1 | 9.4 | 39.0 | 22.0 |
| PN-6 | 79.0 | 40.0 | 47.0 | 26.0 | 5.8 |
| Mean±SD | 89.7±18.6* | 16.2±13.5 | 20.6±14.6 | 64.7±58.3 | 19.1±8.2* |

For abbreviations see Table 1. Mean±SD. Significant difference between PG and PN starches using the paired $t$-test ($^*p<0.05$).

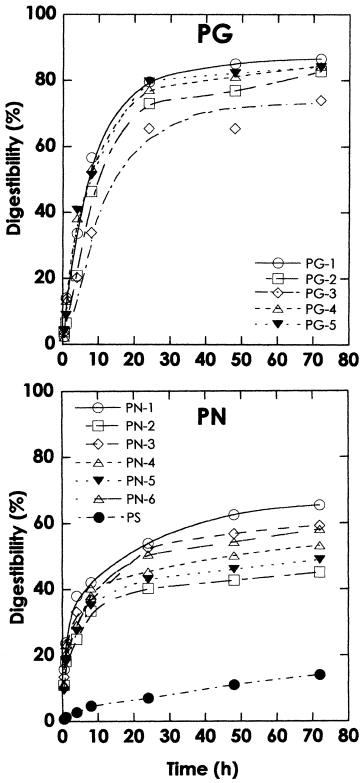


**Fig. 4.** Digestibility of raw PG and PN starches by $\alpha$-amylase.

For abbreviations see Table 1. PS, potato starch. The digestibility was calculated by dividing the amounts of reducing sugars (mg) formed at the elapsed time from 50 mg of raw starch. A significant difference in digestibility between PG starches (82.3±4.8%) and PN starches (55.0±7.5%) at 72 h was obtained using the *t*-test ($p < 0.05$).

granular structure after digestion.

The composition of the oligosaccharides produced by glucoamylase was measured (Table 5). Total oligosaccharide products from the PN-4 starch were 1.23 times as high as those from the PG-4 starch. Glucose was the most abundant (92.9–98.3%), while maltose through maltoheptaose were detected in small amounts (1.7–7.1%). Glucoamylase cuts the starch to a glucose unit from the non-reducing end. The fact that most of the product was glucose could be explained by the high frequency of attack by glucoamylase of the various $\alpha$-1→4 and $\alpha$-1→6 glycosidic bonds.[18]

## CONCLUSIONS

Particle size distribution, crystalline structure, gelatinization property, mineral content and digestibility of crude drug starch by $\alpha$-amylase or glucoamylase were investigated to assess the potential of the starch from the extracted residue of crude drug. Starch contents of C-PGs and C-PNs were 5.0–20.0 and 2.0–5.6%, respectively.

Average diameters of PG and PN starch granules were 6.3±1.1 and 11.0±0.7 $\mu$m, respectively. PG and PN starches were classified as $C_B$-type and $C_A$-type, respectively. The PG-4 and PN-4 starches showed endothermic curves from 44.2 to 69.5 and 51.2 to 72.5°C, respectively, their enthalpy being 8.6±0.4 and 11.7±0.7 J/g, respectively. From the results of X-ray diffraction and thermal

**Table 4.** Composition of oligosaccharides produced from PG-4 and PN-4 starches by $\alpha$-amylase.

| Oligosaccharide | Amount of oligosaccharide ($\mu$g) | |
|---|---|---|
| | PG-4 | PN-4 |
| Maltoheptaose (G-7) | 58.3 ( 3.9%) | 20.3 ( 4.0%) |
| Maltohexaose (G-6) | 77.2 ( 5.2%) | 26.6 ( 5.3%) |
| Maltopentaose (G-5) | 58.3 ( 3.9%) | 19.5 ( 3.8%) |
| Maltotetraose (G-4) | 47.8 ( 3.2%) | 23.9 ( 4.7%) |
| Maltotriose (G-3) | 599.8 (40.6%) | 203.6 (40.2%) |
| Maltose (G-2) | 578.5 (39.1%) | 184.5 (36.4%) |
| Isomaltose (iso-G-2) | 16.8 ( 1.1%) | 6.7 ( 1.3%) |
| Glucose (G-1) | 41.2 ( 2.8%) | 21.5 ( 4.2%) |
| Total | 1477.9 | 506.6 |

The solution of digestibility (PG-4 starch, 13.2%; PN-4 starch, 20.7%) was used. The value in parenthesis is a percentage of each oligosaccharide (G-1–G-7). G-3, 40.2–40.6%; G-2, 36.4–40.6%; G-1+iso-G-2+G-4+G-5+G-6+G-7, 20.1–23.3%.

**Table 5.** Composition of oligosaccharides produced from PG-4 and PN-4 starches by glucoamylase.

| Oligosaccharide | Amount of oligosaccharide ($\mu$g) | |
|---|---|---|
| | PG-4 | PN-4 |
| Maltoheptaose (G-7) | 0.0 ( 0.0%) | 7.3 ( 0.7%) |
| Maltohexaose (G-6) | 2.2 ( 0.3%) | 5.2 ( 0.5%) |
| Maltopentaose (G-5) | 1.3 ( 0.2%) | 8.5 ( 0.8%) |
| Maltotetraose (G-4) | 3.9 ( 0.5%) | 3.7 ( 0.4%) |
| Maltotriose (G-3) | 2.7 ( 0.3%) | 33.6 ( 3.2%) |
| Maltose (G-2) | 1.6 ( 0.2%) | 8.9 ( 0.8%) |
| Isomaltose (iso-G-2) | 3.3 ( 0.4%) | 7.6 ( 0.7%) |
| Glucose (G-1) | 844.0 (98.3%) | 979.2 (92.9%) |
| Total | 859.0 | 1054.0 |

The solution of digestibility (PG-4 starch, 17.6%; PN-4 starch, 27.9%) was used. The value in parenthesis is a percentage of each oligosaccharide (G-1–G-7). G-1, 92.9–98.3%; iso-G-2+G-2+G-3+G-4+G-5+G-6+G-7, 1.7–7.1%.

properties, it was suggested that granular structures of PN starch are more stable to both moisture and heat than those of PG starches.

P contents of PG and PN starches were 56.0–64.0 and 67.0–120.0 $\mu$g/g, respectively. Ca contents of PG and PN starches were 38.0–83.0 and 26.0–180.0 $\mu$g/g, respectively.

The digestibility of raw PG and PN starches was 82.3±4.8 and 55.0±7.5%, respectively, at 72 h. The main oligosaccharide products from the raw PG-4 and PN-4 starches digested by $\alpha$-amylase were maltotriose (40.2–40.6%) and maltose (36.4–39.1%), whereas the main product of glucoamylase was glucose (92.9–98.3%). It was suggested that the thermostability of PG and PN starches digested by glucoamylase was higher than that of starches digested by $\alpha$-amylase.

## REFERENCES

1) H.J. Kim, S.H. Nam, H.S. Kim and S.K. Lee: Studies on the components of Korean *Panax ginseng* C.A. Mayer. *Kor. J. Food Sci. Technol*., **9**, 19–23 (1977).
2) K. Boki, Y. Yamada and K. Isetani: Water sorption properties of powdered crude drugs and hydrophilic function of their

starches. *J. Appl. Glycosci*., **49**, 19–27 (2002).
3) Y. Yamada, K. Boki, A. Matsuyama, M. Takahashi and M. Iwaki: Adsorption of cationic methylene blue and anionic methyl orange by crude drug starches. *J. Appl. Glycosci*., **52**, 101–106 (2005).
4) Editorial Committee of The Japanese Pharmacopoeia (Ed): Loss on drying. in *The Japanese Pharmacopoeia Fourteenth Edition*, I. Suzuki, ed., Hirokawa Shoten, Tokyo, pp. B-114–B-124 (2001).
5) The Pharmaceutical Society of Japan (Ed.): Crude fiber, Total nitrogen and Crude protein and Crude fat. in *Standard Methods of Analysis for Hygienic Chemists–With Commentary*, M. Nishijima, ed., Kanehara Shuppan, Tokyo, pp. 293–294, 272–274 and 322 (1995).
6) The Pharmaceutical Society of Japan (Ed.): Preparation of sample solution and inorganic compound sample. in *Standard Methods of Analysis for Hygienic Chemists–With Commentary*, M. Nishijima, ed., Kanehara Shuppan, Tokyo, pp. 556–558 and 266–267 (1995).
7) H. Fuwa, M. Nakajima, A. Hamada and D.V. Glover: Comparative susceptibility to amylases of starches from different plant species and several single endosperm mutants and their double-mutant combinations with *opaque*-2 inbred Oh43 maize. *Cereal Chem*., **54**, 230–237 (1977).
8) The Pharmaceutical Society of Japan (Ed.): Reducing sugar. in *Standard Methods of Analysis for Hygienic Chemists–With Commentary*, M. Nishijima, ed., Kanehara Shuppan, Tokyo, pp. 311–313 (1995).
9) S. Honda, E. Akao, S. Suzuki, M. Okuda, K. Kakehi and J. Nakamura: High-performance liquid chromatography of reducing carbohydrates as strongly ultraviolet-absorbing and electrochemically sensitive 1-phenyl-3-methyl-5-pyrazolone derivatives. *Anal. Biochem*., **180**, 351–357 (1989).
10) S. Hizukuri and Z. Nikuni: X-ray diffractometric studies on starches. II. Structure of "C"-type crystallite. *Nippon Nogeikagaku Kaishi*, **31**, 525–527 (1957).
11) S. Hizukuri: Crystalline structure of starch granule. in *Handbook of Denpun Kagaku*, Z. Nikuni, ed., Asakura Shoten, Tokyo, pp. 25–34 (1977).
12) T. Hamanishi, T. Hatta, F.S. Jong, K. Kainuma and S. Takahashi: The relative crystallinity, structure and gelatinization properties of sago starches at different growth stages. *J. Appl. Glycosci*., **47**, 335–341 (2000).
13) Y. Yamada, Y. Yuasa, Y. Udaka and K. Takeuchi: Quality estimation by the head number of Tienchi ginseng. *Med. Biol.*, **137**, 145–150 (1998).
14) T. Noda, Y. Takahata and T. Nagata: Factors relating to digestibility of raw starch by amylase. *Denpun Kagaku*, **40**, 271–276 (1993).
15) Y. Sugimoto, Y. Yamashita, N. Inouchi, M. Fujimori, Y. Kawamura and H. Fuwa: Some properties of katakuri (*Erythronium japonicum* Decne) starch. *Denpun Kagaku*, **36**, 265–272 (1989).
16) Y. Sugimoto, N. Inouchi and H. Fuwa: Some properties of starches of loquat (*Eriobotrya japonica Lind* 1) seed. *J. Appl. Glycosci*., **48**, 335–342 (2001).
17) J.F. Robyt and D. French: The action pattern of porcine pancreatic α-amylase in relationship to the substrate binding site of the enzyme. *J. Biol. Chem*., **245**, 3917–3927 (1970).
18) S. Ueda: Decomposition enzyme of starch. in *Handbook of Denpun Kagaku*, Z. Nikuni ed., Asakura Shoten, Tokyo, pp. 91–114 (1977).

## 生薬ニンジン，サンシチニンジン由来の澱粉の特性

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生薬の抽出残渣に含まれている澱粉の有用性を評価するため，澱粉の物理化学的な諸特性を調べた．澱粉（S）は，*Panax ginseng* C.A. Meyer の根，ニンジン（PG）と *Panax notoginseng*（Burk.）F.H. Chen の根，サンシチニンジン（PN）から調製した．PG と PN の粉末生薬には，澱粉が 5.0–20.0，2.0–5.6% 含まれていた（Table 1）．S-PG と S-PN の平均粒子径は，6.3±1.1，11.0±0.7 μm であった（Fig. 1）．S-PG と S-PN の結晶型は，$C_B$，$C_A$ 型であった（Fig. 3）．S-PG-4 と S-PN-4 は，44.2–69.5，51.2–72.5℃ に吸熱曲線を，また，8.6±0.4，11.7±0.7 J/g のエンタルピーを示した（Table 2）．水分と熱に対して，S-PN粒は S-PG 粒よりも安定な構造を持っていると推察された．S-PG と S-PN には，燐が 56.0–64.0，67.0–120.0 μg/g，カルシウムが 38.0–83.0，26.0–180.0 μg/g 含まれていた（Table 3）．S-PG と S-PN の α-アミラーゼによる 72 時間後の分解率は，82.3±4.8，55.0±7.5% であった（Fig. 4）．α-アミラーゼにより生澱粉から生成した（分解率，S-PG-4：13.2%；S-PN-4：20.7%）主な糖類は，三単糖（40.2–40.6%）とマルトース（36.4–39.1%）であった（Table 4）．グルコアミラーゼにより生澱粉から生成した（分解率，S-PG-4：17.6%；S-PN-4：27.9%）主な糖は，グルコース（92.9–98.3%）であった（Table 5）．S-PG-4 と S-PN-4 は，1 時間分解後，α-アミラーゼによって凸凹に侵食されたが，グルコアミラーゼによっては原型をとどめており粒子表面に小粒が付着していた（Fig. 2）．グルコアミラーゼによって分解された S-PG-4 と S-PN-4 の方が，α-アミラーゼによるものよりも，熱安定性の高いことが推察された．