Properties of Starch Noodles as Affected by Sweetpotato Genotype

LILIA S. COLLADO[1] and HAROLD CORKE[1,2]

ABSTRACT

Starch was extracted from 14 sweetpotato genotypes from the Philippines. The Rapid Visco-Analyzer (RVA) viscoamylographs of the starches showed Type A pasting curves, characterized by a high pasting peak followed by a high degree of shear-thinning. The major difference among genotypes was in the sharpness of the peak, with some showing a very sharp peak while others showed a broad peak. This difference was related to time from onset of pasting to peak viscosity, and to stability ratio (holding viscosity/peak viscosity), which were also highly correlated ($r = 0.84$, $P < 0.01$) to each other. Stability ratio was also correlated to noodle firmness ($r = 0.95$, $P < 0.01$), rehydration (cooked weight) ($r = –0.89$, $P < 0.01$), and swelling volume of the starch ($r = –0.62$, $P < 0.05$). The amylose content was correlated significantly only to peak viscosity ($r = –0.84$, $P < 0.01$). Significant differences in texture and cooking quality of the starch noodles produced from the different genotypes was found. It was shown that the RVA viscoamylographs could be used to detect differences in pasting characteristics of sweetpotato starch which are related to quality of noodle produced.

Cereal Chem. 74(2):182–187

Starch noodles, produced from purified starch from various plant sources, are a major category of Asian noodles. In the absence of gluten, pregelatinized starch is used as a binder mixed with ungelatinized starch to facilitate extrusion or sheeting to produce the noodle. The utilization of different raw materials has been studied, such as rice flour (Juliano 1993), legume starches (Lii and Chang 1981, Singh et al 1989, Galvez et al 1994, Jin et al 1994), and tuber and tuber-legume starch blends (Kim and Wiesenborn 1996). From these studies, it was found that the ideal starch base is one with a Type C viscoamylogram pasting profile characterized by the absence of a peak and a viscosity that remains constant or even increases during continued heating and shearing, indicative of good hot-paste stability. Type C starches show restricted swelling and behave like chemically crosslinked starches that exhibit reduced swelling and solubilization (Schoch and Maywald 1968).

Total annual world production of sweetpotato in 1986–88 was 125 million tonnes, 80% of which was produced in China (Scott 1992). Sweetpotato noodles are extensively produced in China, where it is estimated that 28% of the processed sweetpotato is made into starch noodles (Wang et al 1995). This product is also widely consumed in Korea, Vietnam, and Taiwan (Jeong 1992, Quach 1992, Wang et al 1995). Studies on food products based on root crops are of interest to many developing countries because such crops play a vital role in food security (Oke 1990), such as in substitution for expensive wheat imports. The aim of this study was to determine the physical properties of sweetpotato starch from different genotypes, and to relate differences in these properties to quality of noodle produced.

MATERIALS AND METHODS

Starch Preparation

Fourteen sweetpotato varieties (Table I) were provided by the Asian Sweetpotato and Potato Research and Development (ASPRAD) program of the International Potato Center (CIP) in the Philippines. These are widely grown varieties cultivated as postrice crops in the Luzon area. The tubers were processed into starch at the Institute of Food Science and Technology, University of the Philippines at Los Baños. Tubers were washed thoroughly, shredded using a food processor, and further macerated in a blender with tap water (1:1, w/v) for 2 min at medium speed, and filtered through a cheese cloth. The residue was resuspended in tap water (1:0.5, w/v) and macerated in a blender for 2 min. This step was repeated once more, and the filtrate was mixed and passed through a 250-mesh sieve. Starch in the filtrate was allowed to settle for 2-3 hr at room temperature (27–30°C). The supernatant was decanted and discarded; the starch was resuspended in water and filtered through a 250-mesh sieve and kept in the refrigerator (≈7°C) to settle. The last step was repeated once without the sieving step. The starch sediment was dried in a convection oven at 50°C overnight, cooled to room temperature, and equilibrated for 4 hr before samples were packed and sealed in polyethylene bags for shipment to Hong Kong. Subsequent analysis of the starch and preparation of the starch noodles was conducted at the University of Hong Kong.

Analytical Methods

Starch was analyzed for pH (Sentron 2001 instrument, Integrated Sensor Technology, Roden, The Netherlands), moisture (AACC 1995), total starch using a Total Starch Determination Kit (Megazyme Pty, Ltd., Warriewood, Australia), and amylose content by an iodine spectrophotometric method (Williams et al

TABLE I
Starch Content of Isolated Starch Preparation, Amylose Content of Starch, and Swelling Volume and Solubility of Starch of 14 Sweetpotato Genotypes[a]

Genotype	Starch (%)	Amylose (%)	Swelling Volume (mL/g)	Solubility (%)
P16	93.4	20.5	32.9	11.5
20 Caniang	96.7	17.9	35.2	14.4
UPLSP 5	89.1	19.8	33.7	14.0
46 la	91.9	25.3	34.7	14.3
Bataan	92.4	17.8	32.4	12.3
Adams 3	94.5	27.1	32.9	13.0
13b Tres Colores	99.8	23.6	30.9	10.7
88ws623	88.1	16.8	32.9	11.1
93006	92.9	23.3	30.9	13.3
V37-151	96.8	18.0	32.9	14.6
26 Pariados	92.6	22.5	34.3	14.4
UPLSP 1	92.6	21.0	34.8	12.3
G88	91.1	20.7	32.1	12.0
Binicol	92.1	15.3	30.9	10.9
Mean ± SD	93.1 ± 3.1	20.7 ± 3.4	33.0 ± 1.5	12.8 ± 1.4

[a] Moisture free basis. All values are means of two replicate determinations.

[1]Cereal Science Laboratory, Department of Botany, University of Hong Kong, Pokfulam Road, Hong Kong.
[2]Corresponding author. Fax: +852 2858 3477. E-mail: harold@hkuxa.hku.hk

Publication no. C-1997-0207-04R.

1970). Swelling volume (Crosbie 1991) was determined by weighing 0.350 g of starch, db into 125- × 16-mm Pyrex culture tubes to which 12.5 mL of water was added. The tubes were placed in a mixing unit equilibrated at 25°C for 5 min, after which they were transferred to a 92.5°C waterbath and mixed in a prescribed mixing schedule for 30 min. Samples were cooled in ice water for 1 min, placed in a waterbath at 25°C for 5 min and centrifuged at 1,000 × *g* for 15 min. The height of the gel was measured and converted to volume of gel per unit dry weight of the sample. Solubility, expressed as the amount of starch leached out into the supernatant in the swelling volume test, was determined by the anthrone-sulphuric method (Dubois et al 1956) multiplied by 0.9.

Pasting Properties

A Rapid Visco-Analyzer model 3D (RVA) (Newport Scientific Pty. Ltd., Narrabeen, Australia) was used to determine the pasting properties of the starch from different genotypes. A suspension of 3 g (14% mb) starch in 25 g of accurately weighed distilled water underwent a controlled heating and cooling cycle under constant shear where it was held at 50°C for 1 min, heated from 50°C to 95°C at 6°C/min, held at 95°C for 5 min, cooled to 50°C at 6°C/min, and held at 50°C for 5 min (Fig. 1). Pasting parameters of time from onset of pasting to peak viscosity (P_{time}); temperature at which peak viscosity was reached (P_{temp}); peak viscosity (PV); viscosity at the end of hold time at 95°C or hot-paste viscosity (HPV); viscosity at the end of the hold time at 50°C or cool-paste viscosity (CPV); the stability ratio (HPV/PV) and setback ratio (CPV/HPV) were recorded (Fig. 1). All tests were replicated twice.

Thermal Properties

Gelatinization characteristics were determined using a Mettler DSC-20 differential scanning calorimeter (Mettler-Toledo AG Instruments, Naenikon-Uster, Switzerland). Starch samples (2.5 mg, db) were placed in aluminum crucibles. Distilled water was added to make a 1:3 (w/w) starch-water ratio, and the crucible was hermetically sealed. An empty aluminum crucible was used as reference. The gelatinization temperature (°C) parameters of onset (T_o), peak (T_p), conclusion (T_c), and enthalpy (ΔH, J/g) were determined using software provided with the equipment. The range T_r was calculated as $T_c - T_o$. All measurements were replicated twice.

Noodle Preparation

Starch with gelatinized starch (95:5 raw starch to gelatinized starch) was mixed with water to 50% mc. The starch slurry was extruded using a 10-mL syringe into boiling water for 2–3 min (Lii and Chang 1981), transferred to cold water, and drained. Strands were separated and hung to partially dry, kept at 5°C overnight, bundled, dried at 40°C in a convection drier, cooled to room temperature, and sealed in polyethylene bags until used for analysis.

Evaluation of Noodles

Cooking loss (AACC 1995) and texture profile were analyzed after boiling for 4 min (until the hard core of the noodle disappeared), placing in cold water, draining for 5 min, wiping with filter paper, and keeping in a covered petri dish until analysis. Texture analysis was done within 15 min using a QTS-25 texture analyzer (Stevens Advanced Weighing Systems, Leonard Farnell and Co. Ltd., England). A single strand of noodle was laid on the platform securely lined with filter paper fastened by double-sided adhesive tape. The thickness of the noodle was measured, and it was subjected to 75% deformation in compression mode at a probe speed of 1.00 mm/sec, using a cylindrical probe (38 mm) as in the method used by Kim and Seib (1993), but using a single cycle. The maximum force (g) to compress the noodle was noted as firmness while the negative force was noted as adhesiveness (g). A total of 12 texture determinations were made from each batch of noodles and the two extreme readings were removed. The cooking was replicated twice for each sample.

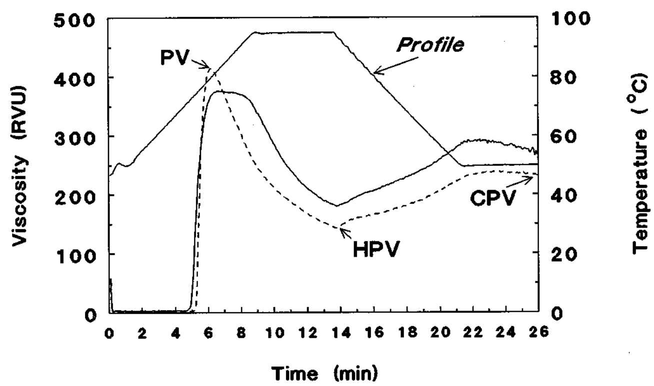

Fig. 1. Typical sweet potato starch viscoamylographs showing the broad peak of 13b Tres Colores (solid line) and the narrow peak of V37-151 (broken line). Position of peak viscosity (PV), hot-paste viscosity (HPV), and cool-paste viscosity (CPV) is indicated on the curve for V37-151. Temperature profile using the right axis is indicated.

TABLE II
Pasting Characteristics of Sweetpotato Starch from 14 Genotypes[a]

Genotype	P_{temp} (ºC)	P_{time} (min)	PV (RVU)	HPV (RVU)	CPV (RVU)	Stability Ratio	Setback Ratio
P16	79.3	1.34	377	171	262	0.46	1.53
20 Caniang	78.3	1.32	409	147	232	0.36	1.59
UPLSP 5	80.0	1.00	406	165	243	0.41	1.47
46 la	78.8	1.26	363	127	208	0.35	1.64
Bataan	82.8	1.40	417	178	260	0.43	1.46
Adams 3	79.2	1.31	329	137	228	0.42	1.66
13b Tres Colores	81.6	1.91	378	190	270	0.55	1.42
88ws623	80.3	1.57	420	186	274	0.44	1.47
93006	79.5	1.47	378	159	247	0.42	1.55
V37-151	80.1	1.11	412	145	234	0.35	1.62
26 Pariados	79.3	1.23	362	137	229	0.38	1.67
UPLSP 1	83.2	1.54	331	154	256	0.47	1.65
G88	79.6	1.72	378	182	282	0.48	1.55
Binicol	84.1	1.67	428	203	284	0.47	1.40
Mean ± SD	80.4 ±1.8	1.4 ± 0.25	384 ± 32	163 ± 23	251 ± 23	0.43 ± 0.06	1.54 ± 0.09

[a] All values are means of two replicate determinations. P_{temp} = temperature at which peak viscosity was reached; P_{time} = time from onset of pasting to peak viscosity; PV = peak viscosity; HPV = hot-paste viscosity; CPV = cool-paste viscosity; RVU = Rapid Visco-Analyzer units.

Statistical Analysis

A completely randomized design was used, and means were analyzed for significant differences using one-way analysis of variance. Where significant differences were found, Duncan's multiple range test ($P < 0.05$) was used to separate means. Pearson correlation coefficients were calculated on pasting characteristics, starch and noodle quality means. All analysis was done using the Statistical Analysis System version 6.10 for Windows (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Starch Samples

The starch samples had an average total starch content of 93.1%, ranging from 88.1 to 99.8% (Table I), comparable to the results reported by Tian et al (1991), which ranged from 83.5 for commercial sweetpotato samples to 98.7% for samples prepared in the laboratory. The highest starch content was in 13b Tres Colores, and the lowest was in 88ws623 (Table I). A wide variation in amylose content was observed by Tian et al (1991), ranging from 8.5 to 37.4%. The average amylose content of our sweetpotato starch samples was 20.7%, ranging from 15.3% in Binicol to 27.1% in Adams 3 (Table I). Differences between studies may be due to many factors such as genotype, environmental factors, starch processing, and methods of analysis. The pH of our starches ranged from 5.9 to 6.8.

Swelling and solubility tests on starch provide evidence for the associative bonding within the granule. The extent of swelling can be plotted against pasting temperature to monitor the progressive relaxation of the bonding forces within the granule. This permits comparison of the relative bond strengths in starch and the temperature (i.e., energy level) necessary to cause relaxation (Leach et al 1959). The method employed in this study used only 92.5°C (near boiling) to approximate conditions during the preparation of noodles. The mean swelling volume of the different genotypes was 33.0 mL/g, in a fairly narrow range from 30.9 (in Binicol) to 35.2 mL/g, (in 20 Caniang) while mean solubility was 12.7% (ranging from 10.7% in 13b Tres Colores to 14.4% in V37-151) (Table I). Swelling volume was correlated ($r = 0.62$, $P < 0.05$) with solubility of the starch. The swelling power at 90–95°C of legume starches were generally low and ranged from 9.3 to 20 g/g (Singh et al 1989, Gujska et al 1994, Jin et al 1994) compared to that of sweetpotato, which ranged from 24 to 33.3 g/g (Tian et al 1991, Jin et al 1994). The high mean swelling volume (33 mL/g) of the sweetpotato starches in this study suggests higher swelling power as compared to that reported for legume starches. This indicates that the associative bonding forces within the granules are rather weak as compared to legume starches, which are strong even at high temperatures. In general, the extent of starch solubilization during pasting parallels the swelling pattern. However the high-swelling characteristic of sweetpotato was not accompanied by high solubility. Solubility data reported for legume starches ranges from 10 to 30% (Lineback and Ke 1975, Singh et al 1989, Gujska et al 1994). Although no legume starch was analyzed in this study, the solubility means fall within the reported range for legumes. This was also consistent with Jin et al (1994), who found solubility of ≈16% for sweetpotato and ≈14% for broad beans and mung bean, although their swelling power (≈24 g/g for sweetpotato and <10 g/g for the bean starches) were very different. This anomalous behavior was also observed by Leach et al (1959), who found that despite its high and unrestricted swelling, potato starch was less soluble at any particular degree of swelling than other starches studied. It was postulated that the bonding forces in potato starch granule are very tenuous but comparatively extensive, immobilizing the starch substance within the granule even at very high levels of swelling. This speculation was also used by Bhattacharya et al (1972) to explain the low amylose solubility in dwarf indica rice varieties that had high equilibrium moisture content like potato starch. This might also have been true for the sweetpotato starches in this study.

Pasting and Gelatinization Properties

Generally, the pasting profiles of sweetpotato starches are Type A defined as high-swelling starch characterized by high pasting peak followed by a high degree of shear thinning (Schoch and Maywald 1968). The most noticeable difference in pasting profiles of our genotypes was in the sharpness of the peak. Some genotypes showed a broad peak almost like a plateau (Fig. 1). Such differences were reflected in the P_{time}, and the stability ratio (HPV/PV) (Table II). The average P_{time} was 1.4 min, and the average stability ratio was 0.43. For the sweetpotato genotypes evaluated, P_{time} was highly correlated with stability ratio ($r = 0.84$, $P < 0.01$). The 13b Tres Colores, with the highest observed stability ratio of 0.55 and the longest P_{time} (1.91 min), had a very broad peak, while V37-151, with the lowest stability ratio of 0.35 and a P_{time} of 1.1 min, had a distinct and sharp peak (Fig. 1). The average peak viscosity (PV) was 385 RVU, ranging from 331 in UPLSP 1 to 428 RVU in Binicol. PV was significantly negatively correlated with amylose content ($r = –0.84$, $P < 0.01$). Significant differences in HPV and CPV were also observed. The average HPV was 163 RVU ranging from 127 in 46 la to 203 RVU in Binicol, while the average CPV was 251 RVU ranging from 208 in 46 la to

TABLE III
Thermal Characteristics of Sweet Potato Starch from 14 Genotypes[a]

Genotype	T_o (°C)	T_p (°C)	T_c (°C)	T_r (°C)	ΔH (J/g)
P16	65.8	75.4	86.9	21.1	14.4
20 Caniang	63.5	73.5	83.9	20.4	13.7
UPLSP 5	65.0	76.2	85.5	20.5	14.2
46 la	65.7	75.9	87.1	21.4	14.8
Bataan	68.2	76.7	87.7	19.5	14.2
Adams 3	63.4	74.5	84.9	21.5	12.5
13b Tres Colores	65.7	75.2	87.3	21.6	14.4
88ws623	62.9	72.7	84.7	21.7	13.6
93006	62.3	71.5	84.6	22.3	12.2
V37-151	66.4	75.7	86.2	19.9	14.1
26 Pariados	67.0	77.3	89.5	22.5	13.9
UPLSP 1	67.1	77.7	89.6	22.5	14.0
G88	62.1	71.0	87.7	25.6	13.7
Binicol	64.8	76.7	89.0	24.2	15.8
Mean ± SD	65.0 ± 1.8	75.0 ± 2.0	86.8 ± 1.8	21.8 ± 1.6	14.0 ± 0.8

[a] All values are means of two replicate determinations. T (°C) = temperature values at onset, peak, conclusion, and range; ΔH = enthalpy.

TABLE IV
Texture and Cooking Quality of Sweetpotato Starch Noodles from 14 Genotypes

Genotype	Adhesiveness (g)	Firmness (g)	Rehydration (%)	Cooking Loss (%)
P16	6.6	299	200	1.5
20 Caniang	5.3	182	273	1.7
UPLSP 5	3.5	207	254	1.2
46 la	2.9	157	279	1.1
Bataan	9.3	298	204	1.5
Adams 3	5.1	245	226	1.9
13b Tres Colores	9.8	437	186	1.4
88ws623	5.2	312	215	1.4
93006	4.4	239	247	1.8
V37-151	5.7	136	290	1.4
26 Pariados	6.7	224	242	1.6
UPLSP 1	14.0	417	193	1.4
G88	6.4	399	192	1.3
Binicol	5.4	379	171	1.7
Mean ± SD	6.5 ± 2.9[a]	281 ± 98[a]	226 ± 38[b]	1.51± 0.2[b]

[a] Each value is a mean of 12 determinations from two replicates
[b] Each value is a mean of 2 replicate determinations.

284 RVU in Binicol (Table II). The average P_{temp} was 80.4°C ranging from 78.3 in 20 Caniang to 84.1°C in Binicol (Table II).

The gelatinization temperatures, as determined through DSC, showed moderate variation. The average T_o was 65.0°C (from 62.1°C in G88 to 68.2°C in Bataan). The average T_p was 75.0 (from 71.0°C in G88 to 77.7°C in UPLSP 1). The average T_c was 86.8°C (from 83.9°C in 20 Caniang to 89.6°C in UPLSP 1). The average ΔH was 14.0 J/g (from 12.2 J/g in 93006 to 15.8 J/g in Binicol) (Table III). These results were comparable to values presented by Tian et al (1991). Sweetpotato has been reported to gelatinize between 58 and 90°C, with a gelatinization enthalpy between 10.0 to 16.3 J/g. P_{temp} correlated with the T_c ($r = 0.59$, $P < 0.05$), but values from the RVA were lower than those from DSC.

Evaluation of Starch Noodles

We used no additives in the starch (other than 5% gelatinized starch) to determine differences in starch noodle quality resulting from differences in native starch properties. Based on texture analysis, a wide variation in firmness was observed among the noodles produced from sweetpotato starch of different genotypes. The average firmness was 281 g (from 136 g in V37-151 to 437 g in 13b Tres Colores). The average adhesiveness of the noodles was 6.5 g (from 2.9 g in 46 la to 14.0 g in UPLSP 1) (Table IV). During cooking, the average rehydration (increase in cooked weight) was 226% (from 171% in Binicol to 290% in V37-151), and the cooking loss was quite low with an average of 1.51% (from 1.1% in 46 la to 1.9% in Adams 3). The relative range of variation in these two cooking quality traits was less than in the other physical property tests (Table IV).

Generally pure sweetpotato starch is considered inferior, relative to other starches like mung bean, for the production of noodles, and this is normally overcome at least partially by additives and other treatments. The formulation of sweetpotato starch often includes the use of potash alum or the addition of elephant yam flour to improve the quality of the noodle produced from it (Timmins et al 1992, Jin et al 1994, Zhang 1995, Lin et al 1995, Wang et al 1995). Lii and Chang (1981) defined the ideal type of starch for starch noodle production as one with high amylose content or high iodine affinity, restricted swelling, and a Type C Brabender viscosity curve. The Brabender amylograph curves of such starches shows no paste peak but rather a very high viscosity that remains constant or continues to increase during the constant temperature, constant shear cooking phase (Schoch and Maywald 1968). This pasting pattern can be observed in legume starches such as lima bean, lentils, garbanzos, yellow peas, and navy bean (Schoch and Maywald 1968), chick peas (*Cicer arientum*), and field bean (*Vicia faba* L.) (Lineback and Ke 1975), azudki bean (*Vigna angularis* cv. Takara) (Tjahjadi and Breene 1984), pigeon pea (*Cajanus cajanus* L.) and mungbean (*Vigna radiata*) (Singh et al 1989), and pinto and navy beans (Gujska et al 1994). A Type C pasting profile of starch was also observed in some genotypes of potato (Red Pontiac and Mainechip) with stability ratio of 0.95–1.00 (Wiesenborn et al 1994). The starch noodle produced from these was comparable to the quality of noodle produced from mungbean starch (Kim and Wiesenborn 1996).

Correlations among cooking quality parameters, starch characteristics, and the pasting attributes were calculated (Table V). Firmness was significantly positively correlated with P_{time} ($r = 0.87$, $P < 0.01$), stability ratio ($r = 0.95$, $P < 0.01$), and P_{temp} ($r = 0.64$, $P < 0.01$). Firmness was negatively correlated to solubility ($r = –0.87$, $P < 0.01$). Amylose content was correlated with PV ($r = –0.84$, $P < 0.01$) and with setback ratio ($r = 0.53$, $P < 0.05$) but not with stability ratio. High amylose content of starch has been suggested as the major factor contributing to the nonexistence of a peak, a high stability during heating, and a high setback during cooling (Lii and Chang 1981, Jin et al 1994). However, findings on potato starch (Wiesenborn et al 1994) imply that other factors may be involved. For their potato genotypes, stability ratio was somewhat correlated with phosphorus content ($r = –0.38$, $P < 0.05$), calcium and magnesium ($r = 0.38$, $P < 0.05$), and (Ca + Mg)/P ($r = 0.43$, $P < 0.01$), rather than with amylose content. Tjahjadi and Breene (1984) compared the pasting profiles of adzuki bean (amylose, 28.8%) and potato starch (amylose, 29.6%). The pasting profile of the bean starch was distinctly Type C, while that of potato starch was Type A. However, Mestres et al (1988) found that rice flour noodles and mungbean starch vermicelli had a starch network linked by junction zones (crystallites) where only amylose-based components would be useful because their melting points are >100°C (boiling point). Jin et al (1994) indicated that it is the insoluble amylose that is more important and better reflects starch noodle quality rather than the total amylose content. Water-insoluble amylose correlated significantly with pasting behavior and textural attributes of rice, and it was established as a key index of rice quality (Shanthy et al 1980). Amylose content is still one of the more difficult starch characteristics to define and compare across studies, due to differences in analytical methods and to genetic and environmental influences on starch structure within and between species. The importance of amylose on the structure of starch noodles has been established, but it appears that physical characterization such as by viscoamylography is a more practical and reliable method for predictive quality evaluation.

Firmness was negatively correlated to rehydration capacity (cooked weight) ($r = –0.94$, $P < 0.01$) and solubility ($r = –0.87$, P

TABLE V
Pearson Correlation Coefficients for Physicochemical and Quality Attributes of 14 Sweetpotato Genotypes[a]

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	P_{temp}	. . .													
2	P_{time}	0.46	. . .												
3	PV	0.21	–0.02	. . .											
4	HPV	0.61*	0.68**	0.55*	. . .										
5	CPV	0.59*	0.73**	0.38	0.95**	. . .									
6	Stability ratio	0.55*	0.84**	–0.09	0.76**	0.81**	. . .								
7	Setback ratio	–0.51	–0.47	–0.69**	–0.91**	–0.73**	–0.59*	. . .							
8	Starch content	–0.05	0.19	–0.15	–0.14	–0.17	0.11	0.11	. . .						
9	Amylose content	–0.44	–0.05	–0.84**	–0.57*	–0.52*	–0.01	0.53*	0.23	. . .					
10	Swelling vol.	–0.38	0.58*	–0.29	–0.69**	–0.64**	–0.62*	0.66**	–0.14	0.09	. . .				
11	Solubility	–0.58*	–0.82**	–0.12	–0.85**	–0.87**	–0.89**	0.68**	0.06	0.22	0.62*	. . .			
12	Firmness	0.64*	0.87**	–0.12	0.73**	0.83**	0.95**	–0.47	0.01	–0.11	–0.47	–0.87**	. . .		
13	Adhesiveness	0.61*	0.45	–0.32	0.22	0.36	0.55*	0.01	0.27	–0.06	0.02	–0.40	0.66*	. . .	
14	Rehydration	–0.67*	–0.75**	0.05	–0.77**	–0.84**	–0.89**	0.53*	0.10	0.16	0.52*	0.91**	–0.94**	–0.55*	. . .
15	Cooking loss	0.05	0.13	–0.11	0.02	0.06	0.06	0.06	0.31	0.06	–0.33	–0.11	0.04	0.02	–0.18

[a] P_{temp} = temperature at which peak viscosity was reached; P_{time} = time from onset of pasting to peak viscosity; PV = peak viscosity; HPV = hot-paste viscosity; CPV = cool-paste viscosity.
[b] *, ** = significant at $P < 0.05$ and $P < 0.01$ respectively.

< 0.01). No correlation was found between cooking loss and solubility of the starch. No sensory evaluation was conducted, but it has been shown that instrumental methods for the evaluation of noodles are useful (Kim and Wiesenborn 1996). Sensory evaluation is recommended to define the correlation of desirable organoleptic quality attributes with instrumental characterization. The cooking loss of the sweetpotato starch noodles (average of 1.51%) was generally lower than reported for mungbean starch, which ranged from 2.93 to 7.68% (Lii and Chang 1981, Galvez et al 1994, Jin et al 1994), and higher than values reported by Kim and Wiesenborn (1996) for starch noodles from potato, which ranged from 0.2 to 1.2%.

The firmness of the noodles was highly positively correlated with some of the RVA pasting characteristics such as P_{time} (r = 0.87, $P < 0.01$), stability ratio (r = 0.95, $P < 0.01$), HPV (r = 0.73, $P < 0.01$), CPV (r = 0.83, $P < 0.01$), and P_{temp} (r = 0.64, $P < 0.05$). Rehydration was significantly negatively correlated to P_{time} (r = –0.75, $P < 0.01$), HPV (r = –0.77, $P < 0.01$), CPV (r = –0.84, $P < 0.01$), and stability ratio (r = –0.89, $P < 0.01$). This provides evidence that pasting parameters of sweetpotato starch can provide information on the quality of noodles produced. Whalen (1995) also showed how RVA viscoamylography can be used to provide process information on some cereal products. Bhattacharya and Sowbhagya (1978, 1979) and Bhattacharya et al (1978) were able to discriminate rice cultivars on the basis of different pasting parameters (discussed by Dengate 1984). Pasting characteristics (i.e., PV, HPV, CPV) and the ratios such as breakdown (HPV/PV), setback (CPV/PV), total setback (CPV/HPV), and relative breakdown (PV–HPV)/CPV–HPV) were also used to distinguish starches of different species of cereals and tubers (Leelavathi et al 1987). This indicates that the RVA may be used as a tool for quality control of both raw materials and process parameters.

SUMMARY AND CONCLUSIONS

These results are for starches from material harvested in a single crop year and location, but for the purpose of our study, we emphasize the consequences of physical (rather than true genetic) diversity in properties over the range reported. Generally, there were significant differences in the pasting profiles of the sweetpotato starches from different genotypes, as observed in the sharpness of the pasting peak in the RVA viscoamylograph. This characteristic was reflected in the duration of P_{time} and the stability ratio. There were also marked differences in the other pasting parameters such as PV, HPV, CPV, and setback ratio among the genotypes studied. The firmness and rehydration of the starch noodles correlated well with particular pasting traits. RVA viscoamylography proved to be a sensitive method for monitoring quality of starch for sweetpotato starch noodle production. The effects of additives and processing interventions for enhanced sweetpotato starch quality are expected to be more effective when applied to starches that already have some of the desirable properties.

ACKNOWLEDGMENTS

We thank Eufemio T. Rasco, Jr., for the supply of the sweetpotato genotypes. Grant support was received from the Hong Kong Research Grants Council and the University of Hong Kong Committee on Research and Conference Grants.

LITERATURE CITED

AACC. 1995. Approved Methods of the American Association of Cereal Chemists, 9th ed. Method 16-50, approved November 1989, reviewed October 1994; Method 44-15, approved October 1975, revised October 1981 and October 1994. The Association: St. Paul, MN.

BHATTACHARYA, K. R., and SOWBHAGYA, C. M. 1978. On viscograms and viscography, with special reference to rice flour. J. Texture Stud. 9:341-351.

BHATTACHARYA, K. R., and SOWBHAGYA, C. M. 1979. Pasting behaviour of rice: A new method of viscography. J. Food Sci. 44:797-804.

BHATTACHARYA, K. R., SOWBHAGYA, C. M., and SWAMY, Y. M. I. 1972. Interrelationship between certain physicochemical properties of rice. J. Food Sci. 37:733-735.

BHATTACHARYA, K. R., SOWBHAGYA, C. M., and SWAMY, Y. M. I. 1978. Importance of insoluble amylose as a determinant of rice quality. J. Sci. Food Agric. 29:359-364.

CROSBIE, G. B. 1991. The relationship between starch swelling properties, paste viscosity and boiled noodle quality in wheat flours. J. Cereal Sci. 13:145-150.

DENGATE, H. N. 1984. Swelling, pasting and gelling of wheat starch. Pages 49-82 in: Advances in Cereal Science and Technology, Vol. 4. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

DUBOIS, M., GILLES, K. A., HAMILTON, J. K., REBERS, P. A., and SMITH, F. 1956. Colorimetric method for determination of sugars and related substances. Anal. Chem. 28:350-356.

GALVEZ, F. C. F., RESURRECCION, A. V. A., and WARE, G. O. 1994. Process variables, gelatinized starch and moisture effects on physical properties of mungbean noodles. J. Food Sci. 59:378-381, 386.

GUJSKA, E., REINHARD, W. D., and KHAN, K. 1994. Physicochemical properties of field pea, pinto and navy bean starches. J. Food Sci. 59:634-636, 651.

JEONG, B.-C. 1992. Sweetpotato processing, marketing and utilization in Korea. Pages 79-85 in: Product Development for Root and Tuber Crops, Vol. 1. Asia. G. J. Scott, S. Wiersema, and P. I. Ferguson, eds. International Potato Center (CIP): Lima, Peru.

JIN, M., WU, J., and WU, X. 1994. A study on properties of starches used for starch-noodle making. Pages 488-496 in: Proceedings 1994 International Symposium and Exhibition on New Approaches in the Production of Food Stuffs and Intermediate Products from Cereal Grains and Oil Seeds. G. Xie and Z. Ma, eds. CCOA/ICC/AACC Meeting. CCOA: Beijing.

JULIANO, B. O. 1993. Major processed rice products. Pages 101-123 in: Rice in Human Nutrition. FAO Food and Nutrition Series No. 26. Food and Agriculture Organization (FAO): Rome.

KIM, W. S., and SEIB, P. A. 1993. Apparent restriction of starch swelling in cooked noodles by lipids in some commercial wheat flours. Cereal Chem. 70:367-372.

KIM, Y. S., and WIESENBORN, D. P. 1996. Starch noodle quality as related to potato genotypes. J. Food Sci. 61:248-252.

LEACH, H. W., McCOWEN, L. D., and SCHOCH, T. J. 1959. Structure of the starch granule. I. Swelling and solubility patterns of various starches. Cereal Chem. 36:534-544.

LEELAVATHI, K., INDRANI, D., and SIDHU, J. S. 1987. Amylograph pasting behaviour of cereal and tuber starches. Starch/Staerke 39:378-381.

LII, C.-Y., and CHANG, S. M. 1981. Characterization of red bean (*Phaseolus radiatus* var. aurea) starch and its noodle quality. J. Food Sci. 46:78-81.

LIN, L., LI, Y., SONG, B., and FU, J. 1995. The present status and improvements of sweetpotato processing technology in Sichuan. Paper presented at the SAPPRAD Sweetpotato Processing Study Tour and Workshop, Pingyin, Shandong Province, China. International Potato Center (CIP): Bogor, Indonesia.

LINEBACK, D. R. and KE, C. H. 1975. Starches and low molecular weight carbohydrates from chick pea and horse bean flours. Cereal Chem. 52:334-347.

MESTRES, C., COLONNA, P., and BULEON, A. 1988. Characteristics of starch networks within rice flour noodles and mungbean starch vermicelli. J. Food Sci. 53:1809-1812.

OKE, O. L. 1990. Food security in developing countries. Pages 121-139 in: Roots, tubers, plantains and bananas in human nutrition. FAO Food and Nutrition Series, No. 24. Food and Agriculture Organization (FAO): Rome.

QUACH, N. 1992. Cassava and sweetpotato processing, marketing and utilization in Vietnam. Pages 67-77 in: Product Development for Root and Tuber Crops, Vol. 1. Asia. G. J. Scott, S. Wiersema and P. I. Ferguson, eds. International Potato Center (CIP): Lima, Peru.

SCHOCH, T. J., and MAYWALD, E. C. 1968. Preparation and properties of various legume starches. Cereal Chem. 45:564-573.

SCOTT, G. J. 1992. Transforming traditional food crops: Product development for roots and tubers. Pages 3-20 in: Product Development for Root and Tuber Crops. Vol. 1. Asia. G. J. Scott, S. Wiersema and P. I. Ferguson, eds. International Potato Center (CIP): Lima, Peru.

SHANTHY, A. P., SOWBHAGYA, C. M., and BHATTACHARYA, K. R. 1980. Simplified determination of water-insoluble amylose content of rice. Starch/Staerke 32:409-411.

SINGH, U., VORAPUTHAPORN, W., RAO, P. V., and JAMBUNATHAN, R. 1989. Physicochemical characteristics of pigeon pea and mung bean starches and their noodle quality. J. Food Sci. 54:1293-1297.

TIAN, S. J., RICKARD, J. E., and BLANSHARD, J. M. V. 1991. Physicochemical properties of sweet potato starch. J. Sci. Food Agric. 57:459-491.

TIMMINS, W. H., MARTER, A. D., WESTBY, A., and RICKARD, J. E. 1992. Aspects of sweetpotato processing in Sichuan Province, People's Republic of China. Pages 217-228 in: Product Development for Root and Tuber Crops, Vol. 1. Asia. G. J. Scott, S. Wiersema and P. I. Ferguson, eds. International Potato Center (CIP): Lima, Peru.

TJAHJADI, C., and BREENE, W. M. 1984. Isolation and characterization of adzuki bean (*Vigna angularis* cv. Takara) starch. J. Food Sci. 49:558-562, 565.

WANG, S., SONG, B., and ZHANG, L. 1995. Status and prospects of sweetpotato processing in China. Paper presented at the SAPPRAD Sweetpotato Processing Study Tour and Workshop, Pingyin, Shandong Province, China. International Potato Center (CIP): Bogor, Indonesia.

WHALEN, P. 1995. Fingerprinting cereal products. Prepared Foods November 47-48.

WIESENBORN, D. P., ORR, P. H., CASPER, H. H., and TACKE, B. K. 1994. Potato starch paste behavior as related to some physical/chemical properties. J. Food Sci. 59:644-648.

WILLIAMS, P. C., KUZINA, F. D., and HLYNKA, I. 1970. A rapid colorimetric procedure for estimating the amylose content of starches and flours. Cereal Chem. 47:411-421.

ZHANG, L. 1995. The present status of sweetpotato production and processing in Shandong Province. Paper presented at the SAPPRAD Sweetpotato Processing Study Tour and Workshop, Pingyin, Shandong Province, China. International Potato Center (CIP): Bogor, Indonesia.

[Received August 6, 1996. Accepted December 9, 1996.]