Use of Wheat-Sweet Potato Composite Flours in Yellow-Alkaline and White-Salted Noodles

LILIA S. COLLADO and HAROLD CORKE[1]

ABSTRACT

Cereal Chem. 73(4):439–444

Chinese-style yellow alkaline noodles (YAN) and Japanese-style white salted noodles (WSN) were prepared from a standard brand of hard red winter wheat flour (Red Bicycle) and from composite flours containing the wheat flour plus 25% sweet potato flour (SPF). SPF from four Philippine genotypes (CL-946-25, Miracle L, CN-941-32, and CL-1489-89) was used. The composite flours showed two distinct gelatinization endotherms corresponding to the two types of starch present. The gelatinization enthalpies of the composite flours were generally slightly lower than all-wheat flour, except for CL-1489-89, which had minimal amylase activity. Rapid Visco-Analyser (RVA) viscoamylographs of composite flours were significantly different under slightly acidic conditions (pH 5.7–6.0) but not under alkaline conditions (pH 10), primarily due to differences in SPF amylase activity. Correspondingly, YAN were firmer and had lower cooking loss than WSN. Sweet potato genotypes differed significantly in the color imparted to the composite flour noodles. The modified Pekar Slick test was conducted on SPF under alkaline and under slightly acidic conditions to show the extent of discoloration during processing. For wheat-sweet potato composite flours, the addition of ascorbic acid tended to increase noodle firmness. However, a higher degree of browning after 24 hr of storage at 4°C was observed in noodles containing ascorbic acid. RVA viscoamylographs and the modified Pekar slick test results can be used to screen sweet potato cultivars for noodle quality.

Roots, tubers, and plantain play a vital role in food security in developing countries. Sweet potato (*Ipomea batatas*) originated in the Yucatan Peninsula of Latin America and is considered to be the most widely dispersed root crop. It grows under many different ecological conditions, has a shorter growth period than most crops, and shows no marked seasonality (Oke 1990). Total world production in 1988 was 125 million tons, of which 108 million tons was produced in China. However, in recent years, there has been a marked drop in sweet potato production in about half its major producing countries. This has been attributed to growth in urbanization and to demand for a more diversified diet based on cereal grains (Scott 1992). The changing food consumption patterns have forced many food-deficit countries to import large quantities of grain to meet local demand. There is now a renewed effort to broaden the food base in developing countries by creating new food products or improving traditional staple food products based on indigenous raw materials such as sweet potato. Development of low-cost convenience food products may stimulate consumption and, hence, demand for this crop (De Ruiter 1975, Wheatley and Brekelbaum 1992). In particular, China is the world's largest producer and consumer of wheat, and much recent attention has focused on the escalating Chinese demand for wheat imports (Wehrfritz 1995, Corke 1995). Use of abundant supplies of sweet potato in China to partially substitute for wheat in high-quality products would help to reduce dependence on expensive grain imports. Researchers have tried to use wheat-sweet potato composite flour in the production of several types of product: Arabic bread (*balady*) (Hamed et al 1973 a,b); doughnuts (Collins and Aziz 1982); chiffon cakes, cupcakes, cookies, and bread (Amante 1993); and noodles (Truong 1992). In this study, we tested the utilization of sweet potato flour (SPF) from four different genotypes in the production of Chinese-style yellow alkaline noodles (YAN) and of Japanese-style white-salted noodles (WSN). Ascorbic acid was reported to possibly inhibit sweet potato amylases (Hagenimana et al 1994); to retard browning reactions (Lea 1992, Lozano et al 1994, Nizar and Fazal 1993, Penfield and Campbell 1990) and can be used as a dough conditioner (Belitz and Grosch 1987, Stear 1990). The use of ascorbic acid to improve the quality of noodles made from SPF was also evaluated.

MATERIALS AND METHODS

Flour Samples

Four sweet potato genotypes (CL-946-25, Miracle L, CN-941-32, and CL-1489-89) were supplied by the Bureau of Plant Industries, National Crop Research and Development Center, Los Baños, Laguna, Philippines. The roots were processed into flours at the Institute of Food Science and Technology, University of the Philippines. The roots were washed, peeled, sliced thinly, soaked in 0.1% sodium metabisulfite, dried in a convection dryer at 50°C, and then ground (Cyclone Sample Mill, Udy Corp., Fort Collins, CO) into a flour that can pass through a 60–80 mesh screen (212 µm aperture). The flours were sealed in polyethylene bags and shipped to Hong Kong. A hard red winter wheat flour (Red Bicycle brand) widely used in Hong Kong for noodle production was purchased from the Hong Kong Flour Mills, Kowloon, Hong Kong. It was used as a control and as the base for mixing the wheat-sweet potato composite flours with SPF. All the experimental work was conducted at the University of Hong Kong.

Analytical Methods

Protein was determined by a Kjeldahl method (AOAC 1990); total free sugar according to Chaplin (1994), reducing sugar content by standard method (AOAC, 1990), moisture according to Davis and Lai (1984); total starch using a Total Starch Determination Kit (Megazyme Pty. Ltd., Warriewood, Australia); amylose according to Williams et al (1970); and diastatic activity by standard method (AACC 1995). Physico-chemical properties measured on 100% SPF and 25% composite sweet potato flour or dough were: pH, dry flour color, modified Pekar slick color, and alkaline Pekar slick color (Miskelly 1984) using a Minolta CR-300 chromameter (Minolta Camera Co., Ltd., Tokyo, Japan). The Pekar slick was prepared by pressing the flour to a smooth surface, immersing in water for 2 min and allowing the sample to stand under a cover glass for 2 hr before color measurements were

---

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

Publication no. C-1996-0530-06R.

taken. A similar method was used to prepare the alkaline Pekar slick by immersion in a solution of *kansui* or lye water (9:1 Na_2CO_3:K_2CO_3). Gelatinization characteristics were also determined using a Mettler DSC-20 Differential Scanning Calorimeter (Mettler-Toledo AG Instruments, Naenikon-Uster, Switzerland). Flour samples (≈3.0–3.5 mg, dwb) were placed in tared aluminum crucibles. Distilled water was added to flour samples to make 1:2 (w/w) flour to water ratio (Lund 1984), after which the crucible was hermetically sealed. An empty aluminum crucible was used as a reference. A heating rate of 10°C/min was used to scan samples from 30 to 110°C. Evaluation of the gelatinization endotherm, i.e., temperatures of transition (T_o onset, T_p peak, and T_c conclusion) and enthalpy (ΔH in J/g) were determined by the data processing software supplied with DSC-20 instrument. Rapid Visco Analyser (RVA) viscoamylographs were determined from 4.00 g of flour (14% moisture basis) in 24 g of distilled water at as is pH (pH ranged from 5.7 to 6.0), and at pH 10 (adjusted with *kansui*) (model 3-D RVA, Newport Scientific Pty. Ltd., Narrabeen, Australia). A programmed heating and cooling cycle was used at constant shear rate, where the sample was held at 50°C for 1 min, heated to 95°C in 7.5 min, held at 95°C for 5.5 min, cooled to 50°C in 7.5 min, and then held at 50°C for 5 min. Duplicate tests were used in each case.

Preparation of Raw Noodles

YAN and WSN were prepared according to the method of Moss et al (1986), using Red Bicycle wheat flour, or 25:75 (w/w) SPF and Red Bicycle flour. For composite flour, the amount of water used in the formulation was increased from 32 to 40%. Where ascorbic acid was added, 1,000 ppm was used (Baik et al 1995). Noodle color after 0, 6, 24, and 48 hr of storage time at 4°C was measured using a Minolta CR-300 chromameter. The noodle dimensions were 1.5 × 6.5 mm, which became 2.0 × 7.0 mm after cooking. Texture and cooking loss of cooked noodles (AACC 1995) were determined after 24 hr of storage. Firmness was measured by compression with a QTS-25 texture analyzer (Stevens Advanced Weighing Systems, Leonard Farnell and Co. Ltd., England) using a shear blade at a crosshead speed of 10 mm/min. The maximum force (*g*) to compress the thickness of the cooked noodle to a distance of 0.5 mm from the baseplate was noted as firmness.

TABLE I
Sweet Potato Flour (SPF) Characteristics of Four Different Genotypes Compared to Red Bicycle Wheat Flour[a,b]

Genotype	Protein (%)	Total Starch (%)	Amylose (%)	Total Sugar (%)	Reducing Sugar (%)	Diastatic Activity
CL-946-25	3.2b	57.1d	17.6b	11.8a	6.1a	10.4a
Miracle L	2.8c	68.4b	17.8b	4.0d	2.2d	5.5b
CN-941-32	2.6c	64.4c	16.5c	10.4b	5.8b	4.2b
CL-1489-89	3.2b	58.4d	20.5a	5.9c	3.8c	1.6c
Red Bicycle	12.7a	73.4a	21.3a	0.9e	0.3e	1.2c

[a] Diastatic activity expressed in maltose equivalent (ME/g of flour). Amylose % based on starch content. All expressed on a dry basis.
[b] Each value is the mean of two replicates. Means followed by the same letter in the same column are not significantly different ($P < 0.001$).

TABLE II
Gelatinization Temperatures[a] of Sweet Potato Flour from Four Different Genotypes Compared to Red Bicycle Wheat Flour

Genotypes	T_o	T_p	T_c	ΔH (J/g)
CL-946-25	73.9a	82.4b	91.9b	6.5c
Miracle L	74.1a	83.3a	92.2ab	8.6b
CN-941-32	69.9b	80.4c	90.6c	8.2b
CL-1489-89	74.2a	83.6a	92.9a	10.0a
Red Bicycle	57.7c	64.7d	76.8d	3.7d

[a] Initial, T_o; peak, T_p; completion, T_c; ΔH, gelatinization enthalpy.
[b] Each value is the mean of two replicates. Means followed by the same letter in the same column are not significantly different ($P < 0.001$).

Statistical Analysis

Analysis of variance (ANOVA) was done to compare flour characteristics and product attribute means from each treatment (type of noodle and ascorbic addition). Where significant differences were found, means were separated using Duncan's multiple range test (SAS 1988).

RESULTS AND DISCUSSION

Flour Characteristics

The SPF ranged from 2.6 to 3.2% protein, 57.1 to 68.4% total starch, and 16.5 to 20.5% amylose content; these values were lower than those of Red Bicycle flour, which were 12.7, 73.4, and 21.3%, respectively (Table I). There were significant differences in all these characteristics, but CL-946-25 was not significantly different from CL-1489-89 in terms of protein and total starch content, and not significantly different from Miracle L in amylose content. The SPF samples were distinctly different in total sugar (range from 5.9 to 11.8%) and reducing sugar (range from 2.2 to 6.1%), which were higher than those found in Red Bicycle flour (0.9 and 0.3%, respectively) (Table I). Diastatic activity of SPF ranged from 1.6 to 10.4 maltose equivalent, while that of Red Bicycle was 1.2 (Table I). In terms of diastatic activity, CL-946-25 was not significantly different from CN-941-32, nor was CL-1489-89 significantly different from Red Bicycle.

Gelatinization Characteristics of SPF and SPF Composite Flours

The temperature range over which gelatinization occurred (69.9–92.9°C) in the SPF, from onset to completion, was generally consistent with values reported for sweet potato starch (60–90°C) by Tian et al (1991), bearing in mind that flour values are expected to be slightly higher than purified starch values. The range in T_p for the four SPF genotypes was fairly narrow at 80.4–83.6°C, and much higher than the Red Bicycle wheat flour (64.7°C). The SPF also had higher ΔH (6.5–10.0 J/g) compared to wheat flour (3.7 J/g) (Table II). SPF composites were expected to have a higher ΔH because of the higher ΔH of SPF, but only the composite with CL-1489-89 was slightly higher than 100% Red Bicycle flour (Table III). It is possible that the amylase activity contributed to the lower ΔH of the composite flours. There were two distinct gelatinization endotherms observed corresponding to the gelatinization of the two starches in the composite flours. The first endotherm ranged from 56.9 to 75.4°C, corresponding to that of wheat starch, and the second endotherm ranged from 73.9 to 88.9°C, corresponding to that of sweet potato starch.

The lower gelatinization temperatures and ΔH of wheat starch when compared to sweet potato could possibly explain the apparent susceptibility of wheat starch to sweet potato amylases. The wheat starch granules would have been almost fully gelatinized as

TABLE III
Gelatinization Characteristics[a] of Composite Flours Made from Red Bicycle Wheat Flour and Sweet Potato Flour (SPF) from Four Different Genotypes[b]

	First Endotherm			Second Endotherm			
Genotypes	T_o	T_p	T_c	T_o	T_p	T_c	ΔH
CL-946-25	58.9a	66.4a	75.1a	75.9ab	79.9c	85.6b	3.1b
Miracle L	57.8ab	65.3a	75.0a	76.1a	82.9a	88.7a	3.7b
CN-941-32	58.9a	65.9a	73.6b	73.9c	79.4c	84.6c	3.2b
CL-1489-89	56.9b	65.9a	75.4a	75.5b	81.6b	88.9a	4.7a

[a] Initial, T_o; peak, T_p; completion, T_c; ΔH, gelatinization enthalpy.
[b] Each value is the mean of two replicates. Means followed by the same letter in the same column are not significantly different ($P < 0.001$).

the optimum temperature for sweet potato diastatic activity of ≈70°C (data not shown) was reached. β-amylase has practically no activity on intact starch granules. Only α-amylase is able to hydrolyze native undamaged starch, and it works much faster on gelatinized starch than on starch granules (Hoseney 1990). This may also explain the great effect of SPF on the pasting properties of the SPF composite flours. McArdle and Bouwkamp (1986) found that diluted sweet potato amylases appeared to act more efficiently on corn mashes. They concluded that other biochemical factors, such as differences in the nature of the starch fraction or enzyme inhibition may be implicated.

Pasting Properties of SPF Composite Flours

There were significant differences in the pasting characteristics, including the peak (maximum viscosity during RVA profile), hot paste (viscosity at the end of the holding period, i.e., at 14 min), and cold paste (viscosity after 5 min at 50°C at the end of the RVA cycle) viscosities of the composite flours in distilled water (Fig. 1A, Table IV). The highest peak and cold paste viscosities were those of Red Bicycle, while the lowest was that of the composite containing CL-946-25. The pasting profiles of the composite flours were characterized by the presence of a shoulder before the peak viscosity was reached. This corresponds to the two distinct gelatinization temperatures of sweet potato starch and wheat starch. The peak viscosity of flour slurries of the composite flour appeared to be significantly affected by diastatic activity. The pH of the flour slurries of composite flour ranged from 5.7 to 6.0, which is within the optimum pH of sweet potato amylases (Hagenimana et al 1994).

Earlier reports have shown that pasting properties obtained by viscoamylography can be correlated to the quality of noodles. In white salted noodles, Oda et al (1980) found that starch pasting properties correlate well with noodle eating quality. High starch paste viscosity is indicative of good eating quality of noodles (Moss 1980, Crosbie et al 1990). Panozzo and McCormick (1993) validated peak viscosity of wholemeal as a rapid early generation screening test for identifying wheat breeding lines suitable for noodle making. Baik et al (1994) showed that in Cantonese (similar to our YAN) and instant noodles, the starch characteristics are less critical than in Japanese *udon* noodles (similar to our WSN). The evaluation of starch by viscoamylography is applicable only to sound wheat. This study showed how partial substitution of wheat with SPF can drastically affect the pasting properties of the composite flours and demonstrated the sensitivity of wheat starch to sweet potato amylases.

It is a common practice in Japan to add sweet potato, waxy corn, or potato starch to noodle dough to improve eating quality (Ding and Zheng 1991). This increases the proportion of amylopectin in the starch fraction, which is associated with high paste viscosity. Low starch paste viscosity, high amylose content, and poor eating quality were positively correlated (Oda et al 1980, Moss 1980). In the composite flours, the presence of sweet potato flour would have slightly increased the proportion of amylopectin, but any anticipated increase in peak viscosity could have been offset by the high diastatic activity of the flour. In addition, amylopectin structure and, hence, pasting properties could differ widely among genotypes. At pH 10, the condition prevailing in alkaline noodle preparation, the pasting profiles of the composite flours and 100% wheat flour showed minimal differences (Fig. 1B, Table IV). The lowest peak viscosity was that of Red Bicycle followed by CL-946-25 and then the other composite flours, which were not significantly different from each other. Red Bicycle was least affected by the alkaline conditions, but it had lower cold paste viscosity when compared to that at pH 6.0 (in distilled water). There were minimal differences in peak viscosities among SPF composite flour samples and there were no significant differences in hot paste or cold paste viscosities under alkaline conditions. These results show the sensitivity of the sweet potato amylases to high pH imparted by lye water.

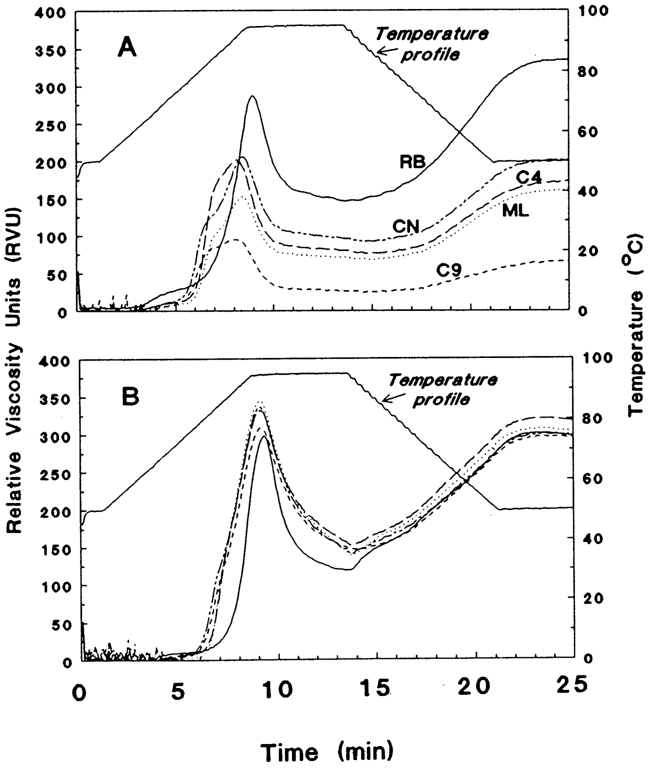

Fig. 1. Rapid Visco-Analyzer (RVA) pasting profiles of composites of 75% Red Bicycle wheat flour and 25% sweet potato flour. A, On "as is" basis (≈ pH 6); B, At pH 10. Sweet potato genotypes: C9 (CL-946-25); ML (Miracle L); CN (CN-941-32); C4 (CL-1489-89); and RB (Red Bicycle).

TABLE IV
Rapid Visco-Analyser (RVA) Peak Viscosity and Cooking Loss for Noodles[a] Made from Wheat-Sweet Potato Composite Flours of Four Different Genotypes and from Red Bicycle Wheat Flour

Genotype	RVA Peak "as is"	WSN Cooking Loss (%)	RVA Peak at pH 10	YAN Cooking Loss (%)
CL-946-25	96.5e	9.1a	308.0b	6.8a
Miracle L	153.5d	7.9c	343.5a	5.6c
CN-941-32	206.5b	8.2b	339.0a	6.0b
CL-1489-89	201.0c	7.2d	333.0a	5.4c
Red Bicycle	288.5a	6.8e	296.5b	4.5d

[a] WSN, white salted noodles; YAN, yellow alkaline noodles.
[b] Each value is the mean of two replicates. Means followed by the same letter in the same column are not significantly different ($P < 0.001$).

TABLE V
Firmness (g) of Yellow Alkaline Noodles (YAN) and White Salted Noodles (WSN) from Wheat-Sweet Potato Composite Flours of Four Different Genotypes and from Red Bicycle Wheat Flour With and Without Ascorbic Acid (Asc)[a]

	WSN		YAN	
Genotype	Without Asc	With Asc	Without Asc	With Asc
CL-946-25	228b	254b	291b	388a
Miracle L	191c	261b	352a	344bc
CN-941-32	214b	237c	308b	363a–c
CL-1489-89	209b	215d	298b	339c
Red Bicycle	284a	284a[b]	372a	372ab[b]

[a] Each value is the mean of 12 replicate measurements. Means followed by the same letter in the same column are not significantly different ($P < 0.001$).
[b] Untreated and included only for comparison.

Hagenimana et al (1994) reported an optimum pH of 5.8–6.4 for α-amylase activity and between pH 5.3 and 5.8 for β-amylase from sweet potato. α-Amylase was more sensitive to acidic pH and may be inactivated almost completely at pH 4.0. It is less sensitive to basic pH and may still have activity at pH 9.0. On the other hand, β-amylase retained its activity in acidic pH up to 3.0 and was inactivated at pH > 8.5. Inactivation of either of the two enzymes by extreme acidity or alkalinity will drastically affect hydrolytic activity because a combination of the two enzymes is necessary for efficiency. Thus, the extreme alkaline condition in the yellow-alkaline noodle formulation would contribute to reduced amylase activity. However, the observed pasting profiles at pH 10 can be attributed to both amylase inactivation and to the direct effect of high pH, which imparts a free swelling property to starch (Lund 1984, Moss et al 1986). The degree of contribution of these two factors to the observed pasting profiles in Figure 1B was not defined. However, 100% wheat flour, which has the least diastatic activity, did not show a big difference in peak viscosity at pH 6.0 (289 RVU) and at pH 10 (297 RVU), implying a significant contribution of amylase inactivation to the observed increased viscosities in composite flours (Table IV).

Evaluation of Noodles

Cooking loss and firmness. Cooking loss was generally lower for YAN than it was for WSN (Table IV). It is interesting to note that the SPF, CL-946-25, with the highest diastatic activity (Table I) showed the highest cooking loss. Generally, SPF samples with high amylase activity showed a higher cooking loss than those with lower diastatic activity. Similarly, it was found that the YAN were firmer when cooked than were the WSN (Table V). Red Bicycle flour also showed lower cooking loss and higher cooked noodle firmness than the SPF composites for both types of noodles.

Orth and Moss (1987) studied different products such as Cantonese noodles, *chapattis,* and pan bread produced from rain-damaged wheat flour. It was found that Cantonese noodle samples had a dark, unattractive appearance; slimy surface; and soft mushy eating quality. They concluded that Japanese type noodles would be even more affected because the high pH of Cantonese noodles restricts some of the enzyme activity.

Color of noodles. The Pekar slick test has long been used by millers to rank flours for whiteness and to indicate sources of discoloration such as bran contamination (Miskelly 1984). In this study, it was used to determine the degree of discoloration that 100% SPF and 25% SPF composite flour would undergo when moistened at slightly acidic (as is) pH and alkaline conditions. The SPF used in this study came from roots with white to yellowish colored flesh. The dry flour brightness (*L*) was minimally different to the Red Bicycle flour control (Table VI). However, when the SPF were moistened, they underwent a drastic color change, which is thought to be dependent on polyphenoloxidase (PPO), substrates and nonenzymatic browning, or a combination of all these. These characteristics are not easily measured and characterized, so the Pekar slick test (Table VI) was used as a rapid and practical method to give an overall assessment of these characteristics. The method can be used for screening of SPF and SPF composite flours and prediction of their relative effects on color of specific end-use product. After 24 hr of storage at 4°C, the noodles from SPF composite samples were generally darker than the all-wheat noodle for both WSN and YAN (Table VII). However, for WSN with genotypes Miracle L and CL-1489-89, the *L* values were minimally (although significantly) different from Red Bicycle. The *a* value of CL-1489-89 was also not significantly different from Red Bicycle. Visually WSN from Miracle L and CL-1489-89 were comparable to the WSN from Red Bicycle.

TABLE VI
Hunter Color Values *(L, a, b)* of Dry Flour and Pekar Slick Color in Distilled Water and in Alkaline Solution for Sweet Potato Flours of Four Different Genotypes and Red Bicycle Wheat Flour

	Dry Flour			Pekar Slick Color			Alkaline Pekar Slick Color		
Genotype	*L*	*a*	*b*	*L*	*a*	*b*	*L*	*a*	*b*
CL-946-25	90.3	0.7	12.0	51.7	5.4	15.9	47.2	9.3	20.4
Miracle L	93.5	0.0	9.1	66.4	2.2	19.3	62.0	2.3	26.6
CN-941-32	90.8	0.6	12.2	57.4	4.1	17.1	54.1	1.9	22.7
CL-1489-89	93.7	–0.2	13.2	65.9	2.0	12.9	62.4	2.1	19.5
Red Bicycle	95.4	0.3	5.2	84.1	–0.2	8.6	82.5	–1.2	13.5

The alkaline salts (*kansui*) confer a unique flavor and quality to Cantonese noodles and are responsible for their yellow color, which is due to interaction with flavonoids present in the flour. Alkaline conditions facilitate the detachment of flavones from polysaccharides and allow manifestation of the yellow color. Alkaline salts toughen the dough and affect pasting properties, as well as inhibit enzyme activity and suppress enzymatic darkening (Miskelly and Moss 1985, Moss et al 1986).

Edwards et al (1989) observed that Korean (salted) noodles darkened less than did yellow alkaline Cantonese noodles. At high pH, activity of phenol oxidases increases and enzymatic oxidation of guiaicol and other substrates is maximal. This was consistent with our findings for YAN from the SPF composites. The contribution of nonenzymatic or carbonyl-amine browning may also be substantial. The factors affecting carbonyl-amine browning include pH, temperature, moisture content, and water activity as well as sugars and amino acids available. This type of browning increases with increasing pH, especially in the pH range 7.8 to 9.2; little, if any, occurs at pH 6 or below (Whistler and Daniel 1985). Browning also increases as temperature increases. Browning rate is higher at low to intermediate moisture levels than at very low levels and is higher at water activity levels between 0.6 and 0.8 than at higher and lower levels. Depending on the product, reducing sugar and amino acid content can be critical factors (Penfield and Campbell 1990). Excessive browning reactions in noodles from SPF with high reducing sugar was due to the additive effect of both enzymatic and nonenzymatic browning.

Effect of Ascorbic acid on the Quality of Noodles

At up to 6 hr of storage, the brightness of SPF composite YAN and WSN with ascorbic acid was higher than that of the noodles without the additive (Fig. 2A–D). The reduction of brightness over time was greater in YAN than in WSN. Ascorbic acid in such a system is known to affect color because it reduces the quinones that are initially formed and thus gives a longer lag phase before it is all consumed and color formation becomes apparent (Nizar and Fazal 1993, Sapers 1993, Pardede et al 1994, Lozano et al 1994, Lea 1992). Ascorbic acid is not involved in nonenzymatic browning, which also seems to be active in the SPF composite flour system, although the addition of ascorbic acid slightly lowered the pH of noodles to 5.0 for the salted noodles and 9.0 for the alkaline noodles. At 24 hr of storage, the noodles with ascorbic

TABLE VII
Hunter Color Values *(L, a, b)* of Uncooked White Salted Noodles (WSN) and Yellow Alkaline Noodles (YAN) After 24 hr of Storage at 4°C[a]

	WSN			YAN		
Genotype	*L*	*a*	*b*	*L*	*a*	*b*
CL-946-25	60.9e	2.7a	14.7b	53.4e	6.5a	16.6e
Miracle L	72.7b	1.4b	16.3a	68.4b	1.6c	20.5a
CN-941-32	67.9d	2.8a	14.6b	64.6d	1.5c	20.1b
CL-1489-89	72.2c	0.5c	11.5c	65.4c	2.6b	18.0c
Red Bicycle	73.4a	0.2c	8.6d	72.3a	–0.4d	17.2d

[a] Each value is the mean of two replicates. Means followed by the same letter in the same column are not significantly different (P < 0.001).

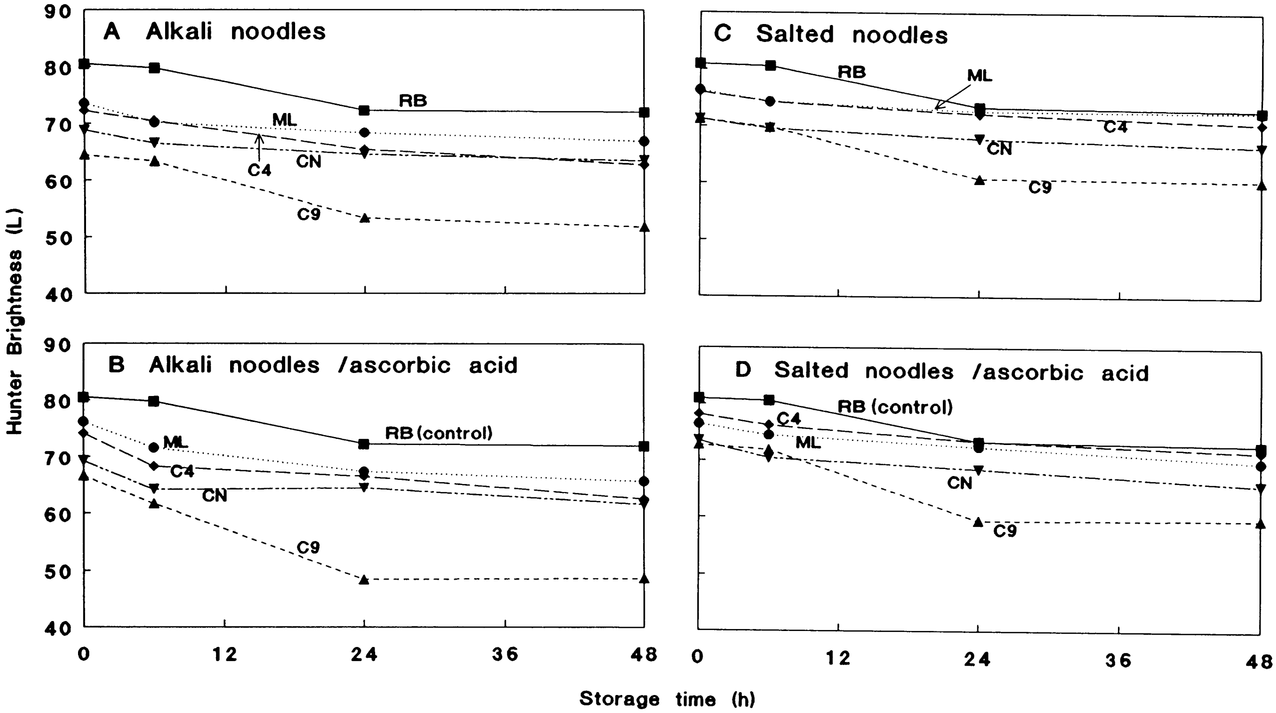

Fig. 2. Changes in Hunter brightness *(L)* values of noodles made from composites of 25% sweet potato flour and 75% Red Bicycle wheat flour with and without ascorbic acid. Yellow alkaline noodles (YAN) made without ascorbic acid (**A**) and with ascorbic acid (**B**). White salted noodles (WSN) made without ascorbic acid (**C**) and with ascorbic acid (**D**). Sweet potato genotypes: C9 (CL-946-25); ML (Miracle L); CN (CN-941-32); C4 (CL-1489-89); RB (Red Bicycle). Graph for Red Bicycle flour in 2B and 2D is a control (without ascorbic acid).

acid exhibited more browning reaction than did the untreated samples. For the cultivars evaluated, Miracle L and CL-1489-89 imparted less discoloration than did CL-946-25 and CN-941-32. Baik et al (1995) showed that a combination of ascorbic acid at a 500 ppm level and vacuum packaging can retard discoloration of noodle dough, and that their effectiveness is different among noodle types, implying that the differences in response could be attributed to differences in pH.

A small amount of ascorbic acid (2–6 g of Asc per 100 kg of flour) caused a pronounced increase in dough strength and bread volume (Belitz and Grosch 1987). The improver effect of ascorbic acid is related to a rapid reaction with endogenous glutathione (GSH), converting it into its disulfide form during dough kneading. Gluten becomes softer in the presence of glutathione because its protein molecules (Pr-SS-Pr) are depolymerized via a thiol-disulfide interchange reaction. By adding ascorbic acid, part of this glutathione is removed from the reaction, resulting in a stronger gluten and, consequently, a stronger dough (Belitz and Grosch 1987, Stear 1990). When ascorbic acid was added to SPF composites, it tended to produce noodles with a firmer texture (Table V). Alkali noodles from composite flour with additive did not differ significantly from those from Red Bicycle in firmness. In salted noodles, although there was also an increase in firmness of noodles when ascorbic acid was added, it was still lower than in 100% wheat flour noodles.

CONCLUSIONS

Noodles produced from composite flours were generally darker in color and softer in texture than noodles from 100% wheat. When ascorbate was added to SPF composites for alkaline noodles, the texture among samples did not significantly differ from control. For salted noodles, ascorbic acid increased firmness but they were still softer than the all-wheat control. SPF composite flours can be used for alkaline noodles. The noodles produced were sufficiently firm with ascorbic acid, but cultivars should be screened for the color imparted, using the modified Pekar slick test. For the cultivars tested, Miracle L and CL-1489-89 composite flours showed promise for alkaline noodles. Initial promising findings suggest that further study on a wide range of sweet potato cultivars for use in alkaline and other noodles should be conducted. However, sensory evaluation using a trained panel is recommended to reaffirm overall acceptability. Further validation of the Pekar slick test for predicting color of end-products from SPF and SPF composites should be done because the test may not be applicable to highly colored varieties.

ACKNOWLEDGMENTS

We thank Dennis Eusebio for the supply of the sweet potato 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

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1995. Approved Methods of the American Association of Cereal Chemists. 9th ed. Method 22-16 approved June 1961, renewed October 1994; Method 16-50 approved November 1989. The Association: St. Paul, MN.

AMANTE, V. R. 1993. Processing of sweet potato flour into bakery products. Pages 134-144 in: Annual Report. 2. Sweet Potato. Southeast Asian Program for Potato Research and Development (SAPPRAD), International Potato Center (CIP): Philippines.

AOAC. 1990. Official Methods of Analysis of the Association of Official Analytical Chemists. 15th ed. Method 988.05 first action 1988, Method 959.11 first action 1959, final action 1960. The Association: Arlington, VA.

BAIK, B.-K., CZUCHAJOWSKA, Z., and POMERANZ, Y. 1994. Role and contribution of starch and protein contents and quality to texture profile analysis of oriental noodles. Cereal Chem. 71:198-205.

BAIK, B.-K., CZUCHAJOWSKA, Z., and POMERANZ, Y. 1995. Discoloration of dough of oriental noodles. Cereal Chem. 72:198-205.

BELITZ, H. D., and GROSCH, W. 1987. Pages 519-520 in: Food Chemistry. Springer Verlag: New York.

CHAPLIN, M. F. 1994. Monosaccharides. Pages 2-3 in: Carbohydrate

Analysis, A Practical Approach. 2nd ed. M. F. Chaplin and J. F. Kennedy, eds. IRL Press: Oxford, UK.

COLLINS, J. L., and AZIZ, N. A. A. 1982. Sweet potato as an ingredient for yeast raised doughnuts. J. Food Sci. 47:1133-1139.

CORKE, H. 1995. International symposium and exhibition on new approaches in the production of food stuffs and intermediate products from cereal grains and oilseeds. Trends Food Sci. & Technol. 6:94-97.

CROSBIE, G., MISKELLY, D., and DEWAN, T. 1990. Wheat quality for the Japanese flour milling and noodle industries. W. Aust. J. Agric. 31:83-88.

DAVIS, A. B., and LAI, C. S. 1984. Microwave utilization in the rapid determination of flour moisture. Cereal Chem. 61:1-4.

DE RUITER, D. 1975. Composite flours. Pages 349-379 in: Vol. II Advances in Cereal Science and Technology. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

DING, X.-L., and ZHENG, J.-X. 1991. Steamed bread and noodles in China. Pages 35-40 in: Proc. Conf. Cereals International, Brisbane, Australia. D. J. Martin and C. W. Wrigley, eds. RACI: Parkville, Australia.

EDWARDS, R. A., ROSS, A. S., MARES, D. J., ELLISON, F. W., and TOMLINSON, J. D. 1989. Enzymes from rain-damaged and laboratory-germinated wheat I. Effects on product quality. J. Cereal Sci. 10:157-167.

HAGENIMANA, V., VEZINA, L.-P., and SIMARD, R. E. 1994. Sweet potato amylase: Characterization and kinetics studied with endogenous inhibitors. J. Food Sci. 59:373-376.

HAMED, M. G. E., HUSSEIN, M. F., REFAI, F. Y., and EL-SAMHY, S. K. 1973a. Preparation and chemical composition of sweet potato flour. Cereal Chem. 50:133-139.

HAMED, M. G. E., HUSSEIN, M. F., REFAI, F. Y., and EL-SAMHY, S. K. 1973b. Effect of adding sweet potato flour to wheat flour on the physical dough properties and baking. Cereal Chem. 50:140-146.

HOSENEY, R. C. 1990. Minor constituents. Pages 102-105 in: Principles of Cereal Science and Technology. Am. Assoc. Cereal Chem.: St. Paul, MN.

LEA, A. G. 1992. Flavor, color and stability in fruit products: The effect of polyphenols. Pages 827-847 in: Plant Polyphenols. R. W. Hemingway and P. E. Laks, eds. Plenum Press: New York.

LOZANO. J. E., DRUDIS, R. B, and IBARZ, A. R. 1994. Enzymatic browning in apple pulps. J. Food Sci. 59:564-567.

LUND, D. 1984. Influence of time, temperature, moisture, ingredients and processing conditions on starch gelatinization. CRC Rev. Food Sci. Nutr. 20:249-273.

McARDLE, R. N., and BOUWKAMP, J. C. 1986. Use of heat treatment for saccharification of sweet potato mashes. J. Food Sci. 51:364-366.

MISKELLY, D. M. 1984. Flour components affecting paste and noodle color. J. Sci. Food Agric. 35:463-471.

MISKELLY, D. M., and MOSS, H. J. 1985. Flour quality requirements for Chinese noodle manufacture. J. Cereal Sci. 3:379-387.

MOSS, H. J. 1980. The pasting properties of some wheat starches free of sprout damage. Cereal Res. Comm. 8:297-302.

MOSS, H. J., MISKELLY, D. M., and MOSS, R. 1986. The effect of alkaline conditions on the properties of wheat flour dough and Cantonese-style noodles. J. Cereal Sci. 4:261-268.

NIZAR, A. M., and FAZAL, U. R. 1993. Ascorbic acid derivatives and polyphenol oxidase inhibitors used to control the enzymatic browning in apples and pears. Sci. Intl. 5:207-210.

ODA, M., YASUDA, Y. OKAZAKI, S., YAMAUCHI, Y., and YOKOYAMA, Y. 1980. A method of flour quality assessment for Japanese noodles. Cereal Chem. 57:253-254.

OKE, O. L. 1990. Pages 129-130 in: Roots, Tubers, Plantains and Bananas in Human Nutrition. FAO Food and Nutrition Series, No. 24. Food and Agriculture Organization of the United Nations (FAO): Rome.

ORTH, R. A., and MOSS, H. J. 1987. The sensitivity of various products to sprouted wheat. Pages 167-174 in: Proc. Intl. Symp. on Pre-Harvest Sprouting in Cereals. D. J. Mares, ed. Westview Press: Boulder, CO.

PANOZZO, J. P., and McCORMICK, K. M. 1993. The Rapid Visco Analyser as a method of testing for noodle quality in a wheat breeding programme. J. Cereal Sci. 17:25-32.

PARDEDE, E., BUCKLE, K. A., and SRZEDNICKI, G. 1994. Control of browning during the thawing of custard apple pulp. Food Aust. 46:205-206.

PENFIELD, M. P., and CAMPBELL, A. D. 1990. Pages 118-119 in: Experimental Food Science. 3rd ed. Academic Press: San Diego, CA.

SAPERS, G. M. 1993. Browning of foods: Control by sulfites, antioxidants, and other means. Food Tech. 47:75-81.

SAS. 1988. Pages 125-154 in: SAS/STAT User's Guide, Release 6.03. SAS Institute Inc.: Cary, NC.

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.

STEAR, C. A. 1990. Pages 36-37 in: Handbook of Bread Technology. Elsevier Applied Science: New York.

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.

TRUONG, V. D. 1992. A consumer-oriented approach for the development of processed sweet potato food products for low and middle income urban groups. Pages 76-82 in: SAPPRAD First Year of Phase III. Annual Reports 1991-1992. Southeast Asian Program for Potato Research and Development (SAPPRAD), International Potato Center (CIP): Philippines.

WEHRFRITZ, G. 1995. Grain drain. Newsweek 125(20):8-14.

WHEATLEY, C., and BREKELBAUM, T. 1992. Integrated root and tuber crop projects: A strategy for product development. Pages 21-22. 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.

WHISTLER, R. L., and DANIEL, J. R. 1985. Carbohydrates. Page 103 in: Food Chemistry, 2nd ed. O. R. Fennema, ed. Marcel Dekker: New York.

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.

[Received October 24, 1995. Accepted April 10, 1996.]