Suitability of Edible Bean and Potato Starches for Starch Noodles

YOUNG S. KIM,[1] DENNIS P. WIESENBORN,[2] JAMES H. LORENZEN,[3] and PATRICIA BERGLUND[4]

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ABSTRACT

Starch noodles were prepared from two types of bean (navy and pinto) starch and three sources of potato starch (ND651-9, Mainechip, and commercial potato starch). Physicochemical properties of those starches, and cooking quality parameters and sensory characteristics of the noodles were investigated. Potato starches contained significantly less amylose and more phosphorus when compared to bean starches. Amylograph pasting properties showed lower pasting temperature and higher peak viscosity for potato starches than for bean starches, but more shear stability for bean starches. Swelling and solubility of potato starches was significantly higher than for bean starches. Noodles made from bean starches exhibited cooking quality similar to that of commercial starch noodles with respect to cooking loss and cooked weight. Texture profile analysis (TPA) results showed starch noodles made from bean starches had higher hardness values, but lower cohesiveness values when compared to those from potato starches. Sensory panelists scored noodles made from potato starches higher in transparency than those made from bean starches. Both transparency and overall acceptability by sensory evaluation were significantly correlated with cohesiveness by TPA. With respect to texture characteristics of starch noodles, starch noodles made from potato starches were more suitable than navy and pinto bean starch noodles.

Starch noodles are one of many popular types of noodles used throughout Oriental countries, as well as in Oriental dishes served in Western countries. This type of noodle is produced by extruding partially gelatinized, gluten-free paste into vermicelli-sized noodles which are often precooked then dried for packaging and marketing. The characteristics of starch noodles, unlike wheat-based noodles, depend heavily upon the functional properties of the starch as it undergoes one or two heat treatments during processing (Mestres et al 1988). Mung bean starch is favored for starch noodle production because it gives a product with the desired appearance and texture. The good quality achieved from mung bean starch is thought to result from the high amylose content and restricted granule swelling. The pasted starch exhibits a stable viscosity during heating and stirring in the Brabender Viscoamylograph test and a high setback on cooling (Lii and Chang 1981).

The dried starch noodles are judged by their uniformity, cooking and eating quality. Galvez and Resurreccion (1992) reported that the absence of color, high glossiness, and high transparency were particularly desired when consumers purchased dry starch noodles. In the case of cooked starch noodles, mouthfeel or texture was the most important characteristic. The noodles should remain firm and not sticky when standing after cooking. Starch noodles should also have a short cooking time with little loss of solids in the cooking water. The taste should be bland.

Starch noodles have been prepared and compared with mung bean starch noodles for starch from pigeonpea (Singh et al 1989); red bean (Lii and Chang 1981); canna, sweet potato, and cassava tuber (Chang and Lii 1987); and rice flour (Mestres et al 1988). Because edible bean (red bean and pigeonpea) starches showed restricted swelling and similar amylogram curves, these starches could be applied as potential starch sources to make starch noodles (Lii et al 1981, Singh et al 1989). Naivikul and D'Appolonia (1979) reported that navy and pinto beans had a higher starch yield than mung bean (40.3 and 38.3%, respectively, vs. 34.5%). The shapes of the amylogram curves of these starches during the holding period at 95°C were similar (no peak viscosity) and indicated that the pastes were stable. Navy and pinto bean starches also had higher amylose contents than did mung bean starch. The above information suggested that starch noodles from navy and pinto bean starch could be of high quality as compared to mung bean starch noodles.

According to LaBell (1990), potato starch in some cases already plays an important role in the production of starch noodles. The noodles reportedly maintain a clear and shiny appearance after cooking, have a smooth and slippery texture, and high absorption of soups and sauces, although supporting data was not included in that report. Our previous study (Kim and Wiesenborn 1995) demonstrated the feasibility of replacing mung bean starch with potato starch for manufacturing starch noodles. The results from sensory evaluation and cooking quality tests of starch noodles made from selected potato starches suggested that the starch from the potato genotype Mainechip was particularly suitable as a starch for the manufacture of starch noodles.

It is important to determine the quality factors that govern the characteristics of starch noodles. Currently, there is little published information on the desired textural properties of starch noodles using instrumental methods. The recently developed Texture Profile Analyzer (TPA) appears to be a promising tool to characterize the texture of starch noodles. The objectives of this research were: 1) to manufacture in the laboratory and characterize starch noodles from navy and pinto bean starch and from different preparations of native potato starch; and 2) to relate the noodle characteristics to certain physicochemical characteristics of the starch.

MATERIALS AND METHODS

Source of Samples

Two types of legumes (navy and pinto beans), which were grown in the 1992 growing season, were obtained from Agrisale, Casselton, ND. Potato tubers of two genotypes (Mainechip and ND651-9) were grown in 1994 at an irrigated site in North Dakota. Commercial (food-grade) potato starch was obtained from Avebe Company (Princeton, NJ). Commercial mung bean starch noodles (SAI FUN Longevity brand bean threads, Hong Kong Food Products Co., Hong Kong) were purchased locally.

Isolation and Purification of Starches

Navy and pinto bean starches were isolated and purified using the procedure of Schoch and Maywald (1968) with minor modifi-

[1]Department of Cereal Science, North Dakota State University, Fargo.
[2]Departments of Agricultural Engineering and Cereal Science, North Dakota State Univ., Fargo, ND 58105-5626 Corresponding author. Fax: 701/231-1008.
[3]Department of Plant Sciences, North Dakota State University, Fargo.
[4]Department of Food and Nutrition, North Dakota State University, Fargo.

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cations. Beans (4 kg) were steeped overnight in distilled water. The pH throughout steeping was adjusted to 6.0 to 6.5 by addition of 1*N* NaOH to preclude acidic hydrolysis. The steeped liquor was decanted, and beans were ground in a Waring blender with distilled water at low speed for 3 min. The slurry was filtered sequentially through a 60-mesh sieve and then through a 200-mesh sieve. The suspension was allowed to settle for 3 hr and the liquid was decanted and discarded. The starch was rinsed three times by resuspending in distilled water, allowing to settle, then decanting the water. The recovered starch was air-dried at room temperature and ground with a mortar and pestle to pass through a 60-mesh sieve. The dried starch was equilibrated at room temperature and humidity for two to three days before transfer to airtight storage containers. Potato starch was isolated and purified as described previously (Wiesenborn et al 1994).

Physicochemical Analysis

Moisture content was determined in triplicate using the method of Wiesenborn et al (1994). Amylose and phosphorus content in the isolated starch were determined in duplicate using slight modifications of the methods of Hovenkamp-Hermelink et al (1988) and Lanzetta et al (1979), respectively. The starch pasting characteristics were determined with a Brabender Viscoamylograph, type VA-1B with a 700-cmg cartridge. A suspension of 3.25% (w/w) starch in 450 ml of deionized water was heated from 30 to 95°C at a rate of 1.5°C/min, held for 15 min at 95°C, then cooled to 50°C at a rate of 1.5°C/min (McComber et al 1988). Paste stability ratio was defined as the ratio of the viscosity at the onset of cooling to the peak viscosity before cooling. Paste setback ratio was defined as the ratio of the viscosity at the completion of cooling to the viscosity at the onset of cooling (Wiesenborn et al 1994). Swelling power and solubility were determined in triplicate at five temperatures ranging from 55 to 95°C by the method of Leach et al (1959).

Starch Noodle Preparation

The procedure for starch noodle preparation described by Lii and Chang (1981) was modified as follows: 95 parts of dry starch were mixed with 5 parts of cooked starch on a dry weight basis to form a dough. Cooked starch was prepared by heating a dry starch and water (1:7, w/v) mixture for 5 min in a 95°C waterbath. The mixture of cooked and dry starch was prepared using a single-speed pin mixer (National Manufacturing Co., Lincoln, NE) for 5 min. The dough, which contained ≈50% moisture, was extruded with a cylinder-type extruder (R. P. C. Testing Machines, Research Products Co., Inc., St. Petersburg, FL) with a Teflon-lined 1.6-mm diameter opening. The maximum extrusion pressure was 1.6 kN. The extruded noodles were immersed in boiling water for 30 sec and cooled by immersion in 15–20°C tap water for 3 min. The noodles were separated and air-dried at room temperature for one day. The dried noodles were stored in sealed polyethylene bags.

Navy and pinto bean starch noodles were prepared as stated above. However, the cooked bean starch did not adequately bind the water. Some water separated from the dough during extrusion. Therefore, the cooked starch used to bind the dry bean starch was prepared from potato starch as described above.

Cooked Weight and Cooking Loss

The cooked weight and cooking loss of starch noodles was determined as described by Galvez and Resurreccion (1992). Starch noodles (10 g) cut into pieces 5-cm long were soaked in 500 ml of distilled water for 5 min, drained, and cooked in a beaker in 300 ml of boiling distilled water for 5 min as previously described (Kim and Wiesenborn 1995). The beaker was covered with aluminum foil to minimize the evaporation losses of water. The cooked noodles were drained and rinsed with distilled water in a Buchner funnel. Cooked weight was determined by weighing the wet mass after the cooked starch noodles were drained for 2.5 min in a Buchner funnel. Cooking loss was determined by evaporating to dryness the combined cooking and rinse water in a preweighed Erlenmeyer glass beaker in an air oven at 110°C. The residue was weighed and reported as a percentage of the weight of dry starch noodles before cooking.

Texture Profile Analysis

TPA of cooked starch noodles was performed as described by Kim and Seib (1993) with minor modifications. Cooked starch noodles were drained for 2 min over a U.S. No. 10 sieve, and noodle strands were placed in distilled water until ready to test. One noodle strand was removed, the excess water was blotted with a tissue, then the strand was placed onto the plexiglass platform. A TA-XT2 Texture Analyser (Texture Technologies Corp., Scarsdale, NY) equipped with the XT.RA Dimension software version 3.7 was used. The sample was compressed with a cylindrical probe (3.8 cm diameter, model TA-4) at a probe speed of 1.0 mm/sec. The compression distance was 90% of the noodle thickness, and the maximum force was set at 2.0 kg-force. Ten individual noodle strands were tested. Typically, readings for several strands deviated widely from the mean. Thus, the five readings with the highest variances from the mean were rejected. Hardness, cohesiveness, and adhesiveness values were obtained by automatic calculation from the TPA curve (Fig. 1).

Sensory Evaluation

Sensory evaluation of the cooked starch noodles was conducted using the line-scaling method (Meilgaard et al 1991). The sensory

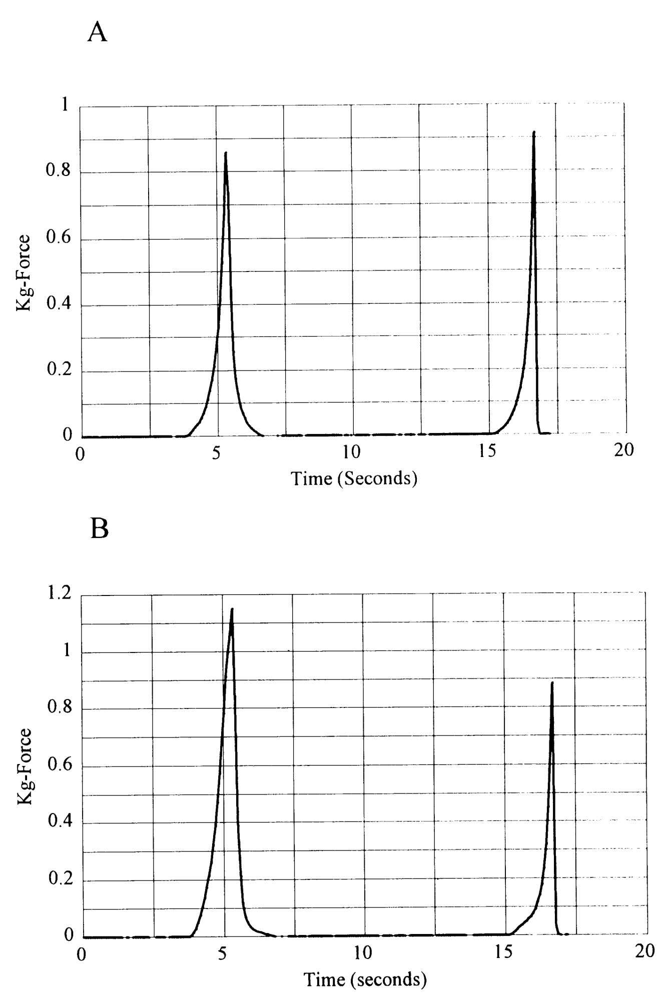

Fig. 1. Texture profile analysis curve of starch noodles made from Mainechip potato starch (**A**) and navy bean starch (**B**).

panel consisted of nine people (three women and six men). Five panelists had participated in a previous starch noodle sensory evaluation and the other four were starch noodle consumers. The sensory panel was trained in the use of the rating method, terminology for each attribute (Table I), and sensory characteristics of starch noodles. Samples were cooked as described above, then evaluated for transparency, slipperiness, firmness, chewiness, and tooth packing. The evaluation was replicated three times over three consecutive days by the full panel.

The panelists marked a vertical line across a 15-cm line at the point that best described each attribute of the starch noodles, with 0 for very low intensity and 15 for very high intensity. Samples were coded with three-digit random numbers, placed in a 1-oz plastic cup and evaluated in booths equipped with white lights at room temperature. Evaluations were conducted in the midmorning.,

Statistical Analysis

The general linear model (GLM) procedure of the Statistical Analysis Program System (SAS 1990) was used. Least significant differences were computed at $P < 0.05$. Differences in each sensory characteristic of each starch noodle product were tested for significance using analysis of variance techniques. Duncan's multiple range test was used as a posthoc procedure when the analysis of variance indicated significant differences in means from sensory evaluation data.

RESULTS AND DISCUSSIONS

Physicochemical Properties of Isolated Starches

The range of moisture content of potato starches was higher (13.5–18.2%) than that of bean starches (10.8–11.0%) (Table II). Potato starch typically has a higher moisture content than the other starches (Swinkels 1985). The amylose contents ranged from 20.0 to 26.5% for potato starches and from 37.3 to 37.8% for bean starches on a dry weight basis (Table II). Among the potato varieties, ND651-9 starch had the greatest amylose content (26.5%), whereas commercial potato starch obtained from Avebe company had the lowest (20.0%). The amylose content range of bean starches was higher than the previously reported range (30.2 and 32.1%) for navy and pinto bean starches (Hoover and Sosulski 1985). High amylose values obtained in this study, as compared to previously reported values, may be attributed to different analytical procedures for assaying the amylose. The phosphorus contents of potato starches were significantly higher (707–918 ppm) than those of bean starches (37–38 ppm). The present results for phosphorus were in line with reported values (Wiesenborn et al 1994, Kim et al 1995). The phosphorus in potato starches is phosphate that is esterified to the starch, whereas in bean starch, phosphorus is present as phospholipids associated with the starch.

The pasting properties by Brabender Viscoamylograph are shown in Figure 2. Key data from the amylograms are also summarized in Table III. The viscosities of three potato starches increased rapidly to peak viscosity and decreased during the holding period at 95°C, because of the granule fragmentation and hydrolysis of amylose chains by hydrogen ions (Hoover and Sosulski 1985). Amylograms for two potato starches, Mainechip and ND651-9, differed from previous data (Kim et al 1995). The previous report for ND651-9 starch showed an amylogram in which viscosity increased throughout the test. In contrast, our present study showed a typical amylogram for starch from this genotype. Mainechip starch showed a much higher pasting temperature and peak viscosity, but much lower peak temperature and setback ratio when compared to previous data. Year-to-year variations in potato starch amylograms were reported previously

TABLE I
Sensory Attributes Evaluated in Sensory Evaluation

Sensory Attributes	Definitions
Transparency	Extent of visibility through the cooked starch noodle strands of objects lying behind them.
Slipperiness	Extent to which the product slides across the tongue.
Firmness	Amount of force required to bite through the starch noodle strands.
Chewiness	Length of time required to masticate one strand of sample at a constant rate of force application to reduce it to a consistency suitable for swallowing.
Tooth packing	Amount of starch noodle left on teeth after masticating one strand of noodle.

TABLE II
Chemical Properties of Potato and Bean Starches

Starches	Moisture, %	Amylose, %	Phosphorus, ppm
Mainechip	13.5	22.7	707
ND651-9	18.2	26.5	918
Avebe[a]	17.6	20.0	752
Navy bean	10.8	37.8	38
Pinto bean	11.0	37.3	37

[a] Commercial potato starch obtained from Avebe Company.

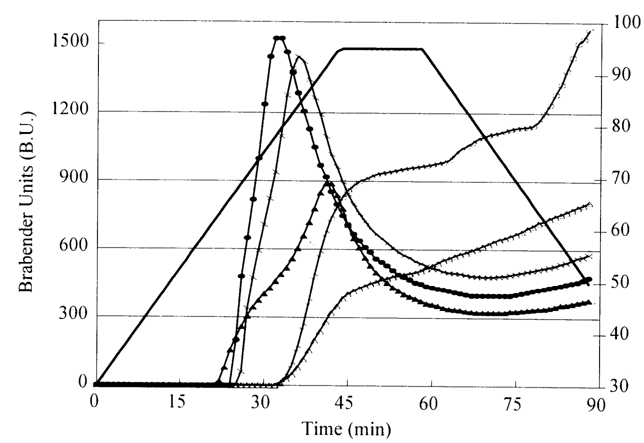

Fig. 2. Brabender amylograms for starch-water suspensions containing 3.25% Avebe potato starch (▲), 3.25% Mainechip potato starch (×), 3.25% ND651-9 potato starch (●), 9.45% navy bean starch (○), and 9.45% pinto bean starch (Δ). Temperature profile is shown with a bold line.

TABLE III
Pasting Properties of Potato and Bean Starches[a,b]

	Pasting Temp.,°C	Peak Temp.,°C	Peak Viscosity, BU	Stability Ratio[c]	Setback Ratio[d]
Mainechip	67.8	84.5	1,450	0.37	1.09
ND651-9	66.5	78.5	1,540	0.29	1.07
Avebe[e]	62.7	92.3	900	0.42	1.03
Navy bean	79.0	. . .	np[f]	1.00	1.62
Pinto bean	79.0	. . .	np	1.00	1.59

[a] Determined using a Brabender Viscoamylograph. BU = Brabender units.
[b] Potato starches prepared as 3.25% starch-water suspensions. Bean starches prepared as 9.45% starch-water suspensions.
[c] Ratio of the viscosity at the onset of cooling to the peak viscosity before cooling.
[d] Ratio of the viscosity at the completion of cooling to the viscosity at the onset of cooling.
[e] Commercial potato starch obtained from Abeve Company.
[f] No peak.

by Wiesenborn et al (1994) and seem to result from differing growing conditions.

In contrast to potato starch, navy and pinto bean starches showed stable amylograms with a gradual increase of viscosity over time. These amylogram patterns were similar to previously reported results (Hoover and Sosulski 1985; Gujska et al 1994). Edible bean starches showed higher pasting temperatures than potato starches, possibly due in part to the high amylose content (Wiesenborn et al 1994). However, starch pasting properties may also be influenced by other factors, such as phosphorus content, degree of branching of amylopectin, starch granule structure, and compositional differences. Similarly, bean starches showed higher stability ratios and setback ratios than potato starches. Amylose contains more intermolecular hydrogen bonding than amylopectin because of structural limitations in amylopectin. Consequently, high-amylose starch would be expected to be more shear stable and, therefore, to have a high stability ratio.

Starch granules, which consist mostly of amylose and amylopectin, are held together by hydrogen bonding in ordered crystalline bundles called micelles (Leach et al 1959). When a starch granule is heated in an aqueous medium, the hydrogen bonds holding the structure weaken, allowing the granule to absorb water and swell. Increases in swelling power and solubility with increasing temperature of potato and bean starches are shown in Table IV. Potato starches showed a much higher swelling power than bean starches. Analogous to the amylograms in Figure 1, potato starch swelling power showed a more marked increase at 65 and 75°C than bean starches. Comparison of swelling powers of the three potato genotypes at 95°C with starch phosphorus content (Table II) suggests a correlation between the two (r = 0.998). The high swelling power of potato starch might be due to the weak internal organization caused by negatively charged phosphate ester groups within the starch granule. Previously, it was shown that phosphorus content is highly correlated with the peak Brabender viscosity (Wiesenborn et al 1994, Kim et al 1995); probably, the high viscosity resulted from the high swelling power, which in turn resulted from high phosphorus content.

In contrast to potato starch, navy and pinto bean starches showed a restricted swelling power of 12.95 and 11.45 at 95°C, respectively. These starches swelled gradually with increasing temperature from 55 to 75°C, but swelled much more above 75°C. The much lower swelling curve of bean starches than potato starches probably resulted in part from the formation of amylose-lipid complexes (Swinkels 1985). Both amylose and lipids are present in much higher amounts in navy and pinto bean starch than in potato starch (Naivikul and D'Appolonia 1979).

The temperature dependence of solubility among potato and bean starches was similar to that of swelling power (Table IV). Potato starches showed higher solubility than bean starches over all temperatures evaluated. This might have resulted from the low lipid content and weak hydrogen bonds within potato starch.

Cooking Quality of Starch Noodles

Cooking quality of starch noodles, determined by cooked weight and cooking loss, is shown in Table V. The cooked weight of noodles made from potato starches were higher than those from bean starches, probably due to the higher swelling power of potato starches. For example, ND651-9 and pinto bean starch noodles, which had the highest and lowest cooked weight, respectively, also had the highest and lowest respective swelling power at 85–95°C. Cooking loss is also an important factor for evaluating starch noodles. Starch structure of starch noodles is maintained as a ramified three-dimensional network that is interlinked by amylose-based crystallites (Mestres et al 1988). Amylose networks swell during boiling in water due to hydration of amorphous regions. The networks are subsequently degraded with increased cooking time, increasing the amylose content of the cooking water. Starch noodles made from potato starches tended to have higher cooking losses than commercial starch noodles, whereas those made from bean starches had lower cooking losses than commercial starch noodles. Thus, even though amylose contents of bean starches were higher than potato starches, the cooking losses of noodles made from bean starches were significantly less. This negative correlation of cooking loss with amylose content was statistically significant (Table VI). The higher lipid and protein contents of navy and pinto bean starches (Hoover and Sosulski 1985, Gujska et al 1994) may play an important role in the retention of amylose in starch noodles during cooking. According to previous reports (Dahle and Muenchow 1968, Grzybowski and Donnelly 1979; Matsuo et al 1986), proteins act as an essential structural component in pasta products, causing noodle strands to integrate and maintain their form during cooking. Lipids form an amylose-lipids complex, resulting in minimized cooking losses. Cooking loss of starch noodles in this study were <10%, which is within the accepted range by Chinese and Thai standards for starch noodles (Lii and Chang 1981, Sisawad and Chatket 1989).

Some textural properties of cooked starch noodles obtained from TPA are summarized in Table V. The hardness, which is defined as the force necessary to attain a given deformation, was obtained from the peak force value corresponding to the first of two successive compressions (Fig. 1). The starch noodles made from bean starches had higher values for hardness than those from potato starches, whereas starch noodles made from potato starches were harder than commercial starch noodles. Although amylose content has been considered an important factor affecting noodle hardness (Dexter and Matsuo 1979, Morrison and Azudin 1987, Toyokawa et al 1989), the correlation between hardness of cooked noodles and amylose content was not significant in this study (Table VI). According to Dexter and Matsuo (1979), the cooked noodle strands containing high or low amounts of amylose were not desirable for spaghetti cooking quality. This suggests that, with respect to noodle cooking quality, if a threshold level of amylose is present, other starch properties are more important than amylose content.

Cohesiveness, which was obtained from the ratio of the peak areas of the force-time plots corresponding to the first and second compressions, is a measure of the extent to which noodle structure was disrupted during first compression. TPA indicated that starch noodles made from potato starches were more cohesive than those from bean starches. Cohesiveness of potato starch noodles was similar to that of the commercial product. The cohe-

TABLE IV
Swelling Power and Solubility of Potato and Bean Starches

	Swelling Power (g/g)					Solubility (%)				
Starches	**55°C**	**65°C**	**75°C**	**85°C**	**95°C**	**55°C**	**65°C**	**75°C**	**85°C**	**95°C**
Mainechip	2.4	2.5	39.7	67.1	104.0	2.5	2.9	14.5	21.3	25.5
ND651-9	2.2	2.7	59.8	74.4	201.4	2.9	3.4	15.1	20.2	68.6
Avebe[a]	2.4	20.5	41.7	56.6	131.1	3.6	9.9	12.1	20.5	56.5
Navy bean	2.3	2.6	4.6	8.3	13.0	0.1	0.5	0.6	10.2	16.3
Pinto bean	2.3	2.6	4.6	7.8	11.5	0.3	0.6	0.9	10.8	17.1

[a] Commercial potato starch obtained from Avebe Company.

starch noodles correlated positively and significantly with phosphorus contents and swelling power (Table VI). Consequently, low cohesiveness of noodles from bean starches may result from insufficient release of amylose due to strong internal bonds, resulting in low solubility and swelling power during cooking (Numtor et al 1995). Adhesiveness values, which represent the work necessary to pull the compressing plunger away from the sample, were <0.004 kg-mm (data not shown). This supported our observation that the noodles had a desirable low stickiness. However, it may be that adhesiveness cannot be adequately measured using one noodle strand.

Starch Noodle Qualities by Sensory Evaluation

Starch noodles from potato and edible bean starches were evaluated for transparency, slipperiness, firmness, chewiness, tooth packing, and overall acceptability (Table I) by sensory evaluation (Table VII). Starch noodles should have a highly transparent appearance. Noodles made from ND651-9 and Avebe starch scored the highest for transparency, whereas noodles from navy bean starch scored the lowest. Previously, it was shown that transparency correlated well with glossiness, another important appearance attribute of starch noodles (Kim and Wiesenborn 1995). Thus, noodles from potato starch had a better appearance than those from edible bean starches. Craig et al (1989) attributed transparency of potato starch to the presence of phosphate esters. The repulsion between these electronegative groups prevents starch molecules from hydrogen bonding to each other, collapsing, and ultimately retrograding. This helps to keep the molecules fully hydrated, promoting high transparency (Craig et al 1989). There was a high correlation ($r = 0.987$, $P < 0.01$) between transparency of cooked starch noodles and phosphorus content in the present study. Transparency also correlated well ($P < 0.01$) with other physicochemical properties of starches, such as pasting temperature ($r = -0.980$), and swelling power ($r = 0.965$).

A very slippery surface texture is also desirable in starch noodles. Mainechip starch and the commercial mung bean starch product scored highest for slipperiness, although not significantly different than ND651-9, navy bean, and pinto bean starches. Only noodles from Avebe starch scored significantly lower.

Cooked starch noodles should be neither too firm nor too soft (Galvez and Resurreccion 1992). In our study, starch noodles from navy and pinto bean starch and Mainechip potato starch scored highest for firmness. Noodles from Avebe starch and the commercial product had lower firmness scores. These data do not indicate, however, whether the higher or lower firmness was most preferred by panelists. Noodles prepared from high-amylose starch are known to be too firm, resulting from a rigid and tight structure that inhibits water absorption (Toyokawa et al 1989). Therefore, an optimum amylose-to-amylopectin ratio is desirable for good noodle quality.

Chewiness was defined as the length of time required to masticate one strand of sample at a constant rate to reduce particle size sufficiently for swallowing. The chewiness of starch noodles made from Mainechip starch, pinto bean starch, Avebe starch, and ND651-9 starch, were not significantly different. Noodles from navy bean starch rated lowest in chewiness. Similar to firmness, chewiness should be neither too high nor too low. However, these data did not show which chewiness values were most preferred. Tooth packing was defined as the amount of starch noodle left on the teeth after masticating one strand of noodle. Thus, a low score is desirable for tooth packing. All noodles were assigned similar, low scores for tooth packing. Panelists did not perceive tooth packing as a problem in this study.

Overall acceptability by the panelists showed a significant difference among starch noodles. The noodles made from Mainechip starch were judged the best among experimental starches but not significantly different from commercial starch noodles. Generally, noodles made from potato starches were ranked much higher than those from bean starches. The overall acceptability and other results from the sensory evaluation showed that noodles made

TABLE V
Cooking Quality and Texture Profile Analyzer (TPA) Data for Starch Noodles

Starches	Cooked Wt. (g)[a]	Cooking Loss (%)[a]	TPA Means[b] Hardness (kg)	Cohesiveness
Mainechip	32.9b[c]	3.4a	1.16bc	0.62a
ND651-9	35.2a	3.3a	1.03c	0.61a
Avebe[d]	29.7d	2.8a	0.85d	0.54b
Navy bean	31.0cd	0.9c	1.24b	0.35d
Pinto bean	28.1e	1.3bc	1.75a	0.41c
Commercial[e]	32.4bc	1.9b	0.77d	0.62a

[a] Values reported are means of two replicates.
[b] Values reported are means of five observations.
[c] Means with the same letter in each column are not significantly different.
[d] Commercial potato starch obtained from Avebe Company.
[e] Manufactured from mung bean starch.

TABLE VII
Sensory Evaluation Scores of Starch Noodles[a]

Starches	Means[b] TR	SL	FI	CH	TP	OA
Commercial[c]	11.21b[d]	11.24a	9.19c	9.03b	4.60b	12.04a
Avebe[e]	11.91a	9.67b	9.20c	10.17a	5.47a	10.09c
Mainechip	10.83b	11.28a	11.16a	10.32a	4.94ab	11.92a
ND651-9	11.93a	10.97a	10.20b	10.11a	5.04ab	11.15b
Navy bean	5.41d	10.86a	11.17a	8.05c	4.82b	7.01d
Pinto bean	6.05c	10.92a	11.80a	10.19a	5.00ab	7.40d

[a] Rating scale; 0 (low) to 15 (high).
[b] TR = transparency; SL = slipperiness; FI = firmness; CH = chewiness; TP = tooth packing; OA = overall acceptability.
[c] Manufactured from mung bean starch.
[d] Means with the same letter in each column are not significantly different.
[e] Commercial potato starch obtained from Avebe Company.

TABLE VI
Correlations Between Cooking Quality and Texture Profile Analyzer (TPA) Data and Physicochemical Properties[a]

Starches	Cooked Wt. (g)[b]	Cooking Loss (%)[b]	TPA Means[c] Hardness (kg)	Cohesiveness
Amylose	−0.378	−0.898*	0.719	−0.864
Phosphorus	0.683	0.962**	−0.711	0.944*
Pasting temp.	−0.448	−0.894*	0.773	−0.858
Swelling power	0.732	0.986**	−0.664	0.974**

[a] * = $P < 0.05$; ** = $P < 0.01$; $n = 5$.
[b] Values reported are means of two replicates.
[c] Values reported are means of five observations.

TABLE VIII
Correlation Coefficients Among Sensory Evaluation Characteristics and Texture Profile Analyzer (TPA) Results for Cooked Starch Noodles[a]

	TPA Parameters Hardness	Cohesiveness
Transparency	−0.776	0.932**
Slipperiness	0.228	0.177
Firmness	0.915*	−0.582
Chewiness	0.131	0.488
Tooth packing	−0.026	−0.016
Overall acceptability	−0.705	0.989**

[a] * = $P < 0.05$; ** = $P < 0.01$; $n = 6$.

from Mainechip had equivalent scores to commercial starch noodles. Thus, Mainechip potato starch appears to be an acceptable alternative to mung bean starch for making starch noodles. This result for Mainechip was in agreement with previous data for overall acceptability based on tubers from an earlier growing season (unpublished data).

Galvez and Resurreccion (1992), using focus groups, reported that texture was considered the most important characteristic of cooked starch noodles, and that cooked starch noodles should be chewy and slippery to maintain a good quality. From the results of sensory evaluation, noodles from potato starch had scores similar to those of the commercial starch noodle product from mung bean starch. Thus, starch from at least some potato genotypes is suitable for commercial manufacture of starch noodles. However, noodles prepared from the navy and pinto bean starch scored lower, especially with respect to transparency and overall acceptability.

Correlations between sensory evaluation scores and TPA parameters of cooked starch noodles are summarized in Table VIII. The firmness by sensory evaluation correlated significantly with the hardness by TPA ($r = 0.915$). Similar findings were also reported in other studies (Walsh 1971, Leung et al 1983, Kim and Wiesenborn 1995). Both transparency and overall acceptability by sensory evaluation were significantly correlated ($P < 0.01$) with cohesiveness by TPA ($r = 0.932$ and 0.989, respectively). However, the other factors assessed in the sensory results and TPA parameters did not give significant correlations. The high transparency of starch noodles and other rheological properties of potato starch pastes are attributable to phosphorus content of the starch granule. Thus, it seems likely that the phosphorus content also contributes to the high cohesiveness of potato starch noodles. The correlation between overall acceptability and cohesiveness suggests that cohesiveness by TPA could be used to screen starch noodle samples prior to sensory evaluation.

CONCLUSIONS

Starch noodles, along with a variety of other East Asian foods, represent a significant and growing market within the U.S. Starch from potatoes and dry edible beans would certainly be competitive with the mung bean starch on a cost basis; if those starches are suitable for manufacture of starch noodles, a new market for these crops could be realized. This study showed that starch noodles of suitable quality were successfully manufactured in the laboratory from certain types of potato starches. This was achieved despite the different physicochemical properties from mung bean starch. Starch noodles from navy and pinto bean starches were of lower quality, even though these starches appeared more similar to mung bean starch than was potato starch with respect to physicochemical properties. Cohesiveness by TPA appears to be a useful instrumental technique; it could be used to rapidly screen starch noodle samples before conducting a more laborious sensory evaluation

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