# Bihon-Type Noodles from Heat-Moisture-Treated Sweet Potato Starch

L.S. COLLADO, L.B. MABESA, C.G. OATES, AND H. CORKE

**ABSTRACT: Sweet potato starch (SPS) has limited uses in the Philippines, but modification of its properties may make it more suitable for use in traditional products that normally use other types of starch. Heat-moisture treatment was applied to native SPS (HMTSPS), which was used as a substrate and composite with maize starch (MS) to produce *bihon*-type starch noodles. Preliminary quality scoring showed that acceptability scores of raw starch noodles, plain boiled, and sautéed noodles made from 100% HMTSPS and 50% HMTSPS:50% MS were not significantly different from the commercial *bihon*. However, consumer testing is recommended to further validate acceptability of the sweet potato for *bihon*.**

**Key Words: sweet potato starch, starch noodles, heat-moisture treatment, Filipino consumer, sensory evaluation.**

## Introduction

ALTHOUGH SWEET POTATOES (*IPOMEA BATATAS* [L.] LAM.; SP) originated in Latin America, 93% of global production is now concentrated in Asia (Oke 1990). Total world production in 1988 was 125 million tonnes of which 108 million tonnes was produced in China (Scott 1992). It is estimated that in China sweet potatoes contribute 33% of the starch for industrial use (Wang and others 1995). Owing to its various agronomic advantages over other root crops, the production potential for sweet potato as a source of starch in the Philippines is great. Identification of new uses for sweet potato starch is necessary to generate demand for it.

Sweet Potato Starch (SPS), like other root crop starches such as cassava, potato, and arrowroot, is considered more free swelling and non-congealing and exhibits a Type A Brabender amylograph, based on viscosity pattern classification by Schoch and Maywald (1968). On the other hand, mung bean starch gives a Type C Brabender amylograph similar to restricted swelling starches (for example, cross-bonded starches). Mung bean starch is well known to be an excellent raw material for starch noodles, giving clear and fine threads that have high tensile strength and low cooking loss even with prolonged cooking. It is believed that such noodle quality is due to its high amylose content, restricted swelling, and a Type C Brabender viscoamylograph pattern (Lii and Chang 1981; Galvez and others 1994; Jin and others 1994; Kim and Wiesenborn 1996).

The term 'hydrothermal treatment' was used by Stute (1992) to describe physical modification of starch resulting from various combinations of moisture and temperature conditions that affect starch properties without visible changes in granule appearance. Physical modification of starch slurries in excess water at temperatures below gelatinization were referred to as annealing. Heat-moisture treatment (HMT), on the other hand, refers to the exposure of the starch to higher temperatures normally above the gelatinization temperature (80 to 120 °C) at very restricted moisture content (< 35%). Results on heat moisture treatment may also have been influenced by partial gelatinization (Eerlingen and others 1996). There is considerable interest in physical modification, as it is considered to be more natural and safe as compared to chemical modification. Kulp and Lorenz (1981), Stute (1992), Hoover and Vasanthan (1994), and Eerlingen and others (1997) investigated the impact of HMT on viscoamylography of potato starch. Either a higher onset of temperature for viscosity development, a lower peak viscosity, or a higher or lower end viscosity was observed, depending on treatment conditions. The same observations were made for cassava (Lorenz and Kulp 1981; Abraham 1993), maize and lentil, oat and yam (Hoover and Vasanthan 1994), and sweet potato (Collado and Corke 1999) starches.

Starches made into noodles offer certain nutritional benefits to consumers. *Bihon* noodles from rice have been demonstrated to lower glycemic blood index of diabetic patients (Panlasigui and others 1990). Starch noodles are retrograded and are, therefore, a source of resistant starch (RS). There is considerable interest in the nutritional implications of RS in foods, since a relatively slow rate of starch hydrolysis in the gastrointestinal tract of humans may have some of the physiological effects of dietary fiber (Englyst and others 1992).

In the Philippines, rice flour, maize starch (MS), and mung bean starch are made into starch noodles locally known as *bihon* for those with thin strands and *pancit malabon* for those with thick strands. *Sotanghon*, the high-quality noodles from mung bean, are the most expensive starch noodles and are known for their high tensile strength, clarity and chewy texture. In this study, the physical modification of SPS was undertaken to produce noodles acceptable to the Filipino consumer. Specifically, the study tested the use of heat-moisture treatment (HMT) as a means to modify SPS and evaluated its use in different proportions with MS to develop a *bihon*-type starch noodle.

## Materials and Methods

### Sweet potato starch and maize starch

Commercial SP variety "Super Bureau," widely grown in Tarlac and Pangasinan Provinces, and characterized by smooth reddish skin and white colored flesh, was purchased from the market in Manila, Philippines. Tubers were washed thoroughly, macerated using a mechanized grater, diluted 1:1 w/v with tap water and filtered through cheesecloth. The residue was resuspended in tap water (1:0.5 w/v), filtered again

(2×), and allowed to pass through a 250-mesh sieve. Starch in the filtrate was allowed to settle for 3 to 4 h at roomtemperature (27 to 30 °C). The supernatant was decanted and discarded while the starch was resuspended in water (2×) and kept at 7 °C to settle. The starch sediment was dried in a convection oven at 50 °C overnight, cooled to room temperature, and equilibrated for 4 h before samples were packed and sealed in polyethylene bags. Commercial maize starch was purchased at the Los Baños Public Market, Laguana, Philippines.

### Starch physicochemical characteristics

Starch was analyzed for pH (Sentron 2001, Integrated Sensor Technology, Roden, The Netherlands), moisture (AACC 1995), total starch using a Total Starch Determination Kit (Megazyme Pty. Ltd., Bray, Ireland), and amylose content by an iodine spectrophotometric method (Juliano 1985). Swelling power was determined as described by Subramanian and others (1994) with minor modifications. Starch (0.6 g) was heated with 30 ml of water to the desired temperature for 30 min. Lump formation was prevented by mixing in a Vortex mixer. The mixture was centrifuged at 3,500 rpm for 15 min. The supernatant was removed, and the swollen starch sediment was weighed. Swelling power was the ratio in weight of the wet sediment to the weight of the initial dry starch. Solubility, expressed as the percent amount of starch leached out into the supernatant in the swelling power determination, was calculated by transferring the supernatant above the gel into an aluminum pan and drying at 110 °C overnight.

### Pasting properties

A Rapid Visco-Analyzer model 3D (RVA; Newport Scientific Pty. Ltd., Warriewood, Australia) was used to determine the pasting properties of the starch samples. A suspension of 3 g (14% m.b.) starch in 25 g of 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 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. The following data were recorded: 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); breakdown, PV less than HPV; viscosity at the end of the hold time at 50 °C or cold paste viscosity (CPV); and setback ratio (CPV/HPV). 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 d.b.) 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 parameters (in °C) of $T_o$ to onset, $T_p$ to peak, $T_c$ to conclusion, and enthalpy ($\Delta H$, J/g) were determined using software provided with the equipment, and the range $T_r$ was calculated as $T_c$ to $T_o$. All measurements were replicated twice.

### Heat-moisture treatment of sweet potato starch (HMTSPS)

The SPS were adjusted from 27% to 30% moisture and equilibrated at 4 to 5 °C overnight (refrigerated condition) and placed in a covered baking pan for 3 h at 110 °C. The sample were cooled to room temperature (about 27 °C) and dried at 50 °C, equilibrated for 4 h and sealed in polyethylene bags until use.

### Laboratory-scale noodle extruder

A laboratory-scale noodle extruder was fabricated, consisting of a stainless steel cylinder wherein the starch dough (capacity about 200 g) is pushed through the die by a manual hydraulic press. The die end of the cylinder can be changed to produce noodles of different diameters. The extruded noodles fall directly into boiling water in a kettle fitted with a stainless steel strainer that can be removed when cooking time has been reached and that can be transferred to the cooling water in another container. All surfaces in contact with the starch dough were made of stainless steel to minimize browning in the product.

### Preparation of starch noodles

Starch dough was prepared by partial gelatinization of 5% (w/w) of the total starch to be used which serves as binder. Gelatinization was done by boiling starch and water (1:7 w/v) for 5 min. Gelatinized starch was then mixed with the remaining 95% ungelatinized starch to form a dough at 55% moisture. The dough was kneaded in a National Automatic Bread Maker for 20 min or until a uniform consistency was achieved. The starch dough was extruded using the fabricated extruder into boiling water for 2 to 3 min (Lii and Chang 1981), transferred to cold water, drained (3×), and dried at 40 °C in a convection drier, cooled to RT, and sealed in polyethylene bags until used for analysis and sensory evaluation. *Bihon*-type starch noodles were made from native SPS, MS, HMTSPS, and composite (50:50 HMTSPS:MS).

### Evaluation of noodles

The cooking procedure for the noodles was a modification of the AACC (1995) method for spaghetti. Starch noodles (5 g) were cut into 5-cm lengths and cooked in 200 ml boiling distilled water in a covered beaker. Optimum cooking time was determined by the removal of a piece of noodle every 30 s and pressing the noodle between 2 pieces of watch glasses. Optimum cooking is achieved when the center of the noodles becomes transparent or when the noodle is fully hydrated (AACC 1995). Cooking was stopped by rinsing briefly in water.

Cooking loss was determined by evaporating to dryness the cooking water and rinse water in a preweighed 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.

Rehydration weight was determined by weighing the wet mass after cooked noodles were drained in a strainer for 2 min, and the excess moisture on the surface was wiped with paper towel. The cooked noodles were stored in a covered Petri dish to minimize drying.

Texture analysis was done within 15 min using a TA-XT2*i* Texture Analyzer (Texture Technologies Corp., Scarsdale, N.Y., U.S.A., and Stable Micro Systems, Godalming, Surrey, 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; the lowest point in the texture graph while the probe was being brought to original position was noted as adhesiveness (g).

### Sensory evaluation

The starch noodles were presented to the panelist as raw uncooked noodles, plainly boiled, and as sautéed noodles. The raw noodles were packed in polyethylene bags that were not sealed so as panelists can examine samples. The plainly boiled noodles were cooked based on optimum cooking conditions earlier determined and served within 20 min to panelists. For sautéed noodles, the noodles were cooked in measured seasonings (soy sauce, garlic, onions), vegetables (carrots, beans), boiled chicken meat and soup stock; however, only noodles (devoid of vegetables and meat slices) were served to panelists for evaluation. Likewise, samples were served to panelists within 20 min after cooking. Sensory evaluation of the 3 sets of noodle samples were evaluated on separate days. A modified 5-point quality scoring of raw starch noodles for the sensory attributes, color, clarity, pliability, and general acceptability were used while for plain boiled starch noodle and sautéed starch noodles cooked as *pancit guisado*, the sensory attributes color, firmness, clarity, flavor, and general acceptability were evaluated by 12 semi-trained panelists consisting of research staff from the Institute of Food Science and Technology (Lawless and Heymann 1999). All panelists were regular consumers of *bihon,* and 2 sessions were devoted to defining and to establishing concept boundaries/ranges for descriptive terminologies by using commercial bihon samples as examples. Another set of sensory evaluation of sautéed starch noodle samples was conducted using untrained panelists made up of 12 housewives who regularly cook and consume *bihon* noodles. Noodle samples were sautéed in a manner similar to the earlier sensory evaluation using semi-trained panelists. Housewives/panelists were not trained and were simply asked to rate samples, using a 5-point scale, the intensity of liking for the product based on defined quality attributes, such as color, texture, flavor, and general acceptability. A *primera* or 1st class *bihon* sample was used as control.

### Statistical analysis

The sensory attribute means for each treatment were subjected to an analysis of variance (AOV) and where significant differences were found, the means were separated by Duncan's Multiple Range Test (DMRT). Correlation coefficients of the sensory attribute mean scores, flavor, and acceptability scores of raw, boiled, and sautéed noodles were determined (SAS 1988).

## Results and Discussion

### Starch samples

*Pasting properties.* Schoch and Maywald (1968) attempted to classify viscosity patterns from the Brabender amylograph namely as: Type A, high swelling starches (potato, tapioca, waxy cereals, ionic starch derivatives) that show a high pasting peak followed by rapid and major thinning during cooking; Type B, moderate-swelling starches (normal cereal starches) that show lower pasting peak and much less thinning; Type C, restricted swelling starches (for example, cross-bonded starches, legume starches) that show no pasting peak by high viscosity that remains constant or increases during cooking; Type D, highly restricted swelling (starches with more than 55% amylose content) that do not swell sufficiently to give a viscous paste when cooked at normal concentrations. Hence the amount of starch must be increased 2- or 3-fold to give a significant hot-paste viscosity similar to Type C starches. Based on this classification, using a Rapid Visco-Analyser to give results comparable to the Brabender Viscoamylograph, the native SPS was Type A, the commercial MS was Type B, while the heat-moisture treated HMTSPS was similar to a Type C (legume starch or cross-linked starch; Figure 1). After heat-moisture treatment, the peak viscosity (PV) was greatly reduced from 4598 to 3109 cP. Furthermore, the breakdown was reduced to 51 from 2227 cP, and the cold paste viscosity (CPV) was greatly increased from 3422 to 5184 cP. The RVA viscoamylograph of commercial maize starch had a PV of 2768 cP, a breakdown of 1283 cP, and a CPV of 2817 cP.

### Starch properties

The amylose content of SPS (19.5%) and commercial maize starch (20.7 %) were almost similar, yet they have a remarkably different functionality in terms of viscosity, swelling power, and solubility (Table 1). Native SPS had high swelling power (27.7 g/g) and low solubility (10.5%), in contrast to maize starch with a swelling power of 20.0 g/g and a solubility of 22.3%. Native SPS and MS gel viscoelastic properties were "long" and "short," respectively, but HMTSPS had a "short" viscoelastic gel and low swelling power compared to native SP and MS. HMTSPS showed a higher gelatinization temperature and wider range (75.0 to 94.4 °C) compared to native SPS (72.5 to 90.6 °C). Earlier work (for example, Abraham 1993; Stute 1992) demonstrated that root crop starches, such as potato and cassava, respond more to HMT than cereal starches, possibly due to greater hydration due to its ionic nature in root crop compared to cereal starches. Swelling and amylose leaching generally decrease after HMT (for example, Sair 1964; Kulp and Lorenz 1981; Hoover and Vasanthan 1994; Hoover and Manuel 1996; Eerlingen and others 1997; Collado and Corke 1999). An increased solubility was observed for some HMT cereal starches, for example, wheat (Kulp and Lorenz 1981) and barley and triticale (Lorenz and Kulp 1981).

### Evaluation of SPS as substrate for noodles

Starch products, such as noodles, lack the gluten of wheat flour products that allows dough development and binding for easy handling during processing. In the production of starch noodles (mung bean, sweet potato), a portion of the starch is gelatinized (cooked into a paste) and mixed with dry starch and water to the right consistency (about 50% moisture content), extruded into boiling water, and

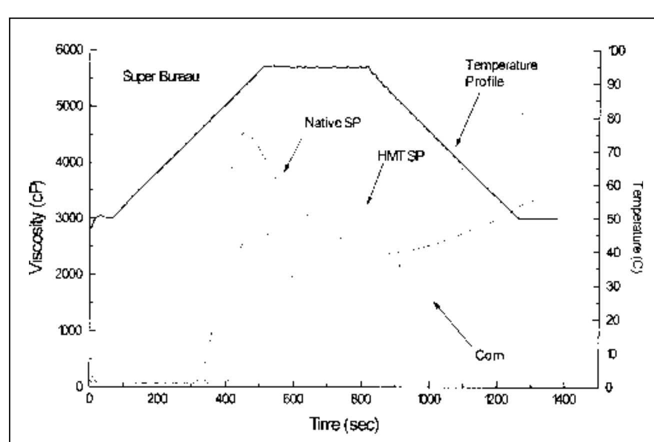


**Figure 1—The RVA viscoamylogram of native and heat moisture treated (HMT) sweet potato (SP) starch from Super Bureau and commercially available maize starch**

**Table 1—The physico-chemical properties of native and heat-moisture treated (HMT) sweet potato starch (SPS) from a commercial variety, Super Bureau, as compared to a commercially available maize starch.**

| | Super Bureau | | Maize starch |
|---|---|---|---|
| | Native | HMT | Native |
| **Pasting properties** | | | |
| Peak (cP) | 4598 | 3109 | 2768 |
| Hot Paste (cP) | 2371 | 3058 | 1485 |
| Breakdown (cP) | 2227 | 51 | 1283 |
| Cold Paste (cP) | 3422 | 5183 | 2817 |
| Setback (cP) | 1051 | 2125 | 1332 |
| Peak time, (min) | 7.6 | 11.8 | 8.3 |
| Peak T, (°C) | 89.5 | 95.0 | 93.5 |
| **Gelatinization Characteristics** | | | |
| $T_o$ (°C) | 72.5 | 75.0 | 73.8 |
| $T_p$ (°C) | 77.8 | 85.2 | 79.7 |
| $T_c$ (°C) | 90.6 | 94.4 | 90.9 |
| $T_r$ (°C) | 18.1 | 19.4 | 17.1 |
| H (J/g) | 14.4 | 13.6 | 10.9 |
| **Other properties** | | | |
| Swelling Power (95 °C), g/g | 27.7 | 15.3 | 20.0 |
| Solubility (95 °C), % | 10.5 | 10.9 | 22.3 |
| Gel viscoelastic property | long | short | short |
| Amylose Content (%) | 19.5 | - | 20.7 |
| Moisture Content (%) | 15.6 | 12.5 | 14.5 |

Each value is a mean of 2 replicate determinations.

washed in cold water, stored under refrigeration or freezing temperature, and dried under the sun (Wang 1983; Timmins and others 1992). Generally, native sweet potato starch is considered inferior to other starches (for example, mung bean) for the production of noodles, and this is normally partially overcome by use of additives and other treatments. The formulation of sweet potato starch noodles often includes the use of potash alum or elephant yam flour to improve the quality of the noodle produced from it (Timmins and others 1992; Jin and others 1994; Zhang 1995; Lin and others 1995; Wang and others 1995). Lii and Chang (1981) defined the ideal type of starch for starch noodle production as 1 with high amylose content or high iodine affinity, restricted swelling and solubility, and a Type C Brabender viscosity curve. This pasting pattern is most often observed in legume starches. A Type C pasting profile was also observed in some potato genotypes with stability ratio of 0.95 to 1.00 (Wiesenborn and others 1994). The starch noodles produced from these were comparable in quality to those produced from mung bean (Kim and Wiesenborn 1996). In starch vermicelli only, amylose-based components (with melting points higher than 100 °C) would contribute to a starch network linked by junction zones (Mestres and others 1988). Jin and others (1994) indicated that insoluble amylose better reflects starch noodle quality than total amylose content. 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 method for predictive quality evaluation.

### Starch noodle evaluation

In the Philippines, the most widely consumed starch noodles (termed *bihon*) were originally produced from broken rice. However, maize starch is now used because it is cheaper and easier to process into noodles. Soaking, washing, and wet milling of rice are no longer needed when maize starch is used (Carpio and others 1990). Most consumers are totally unaware of the shift to maize because producers of *bihon* still indicate rice as the major ingredient in the package label. Commercial processing of *bihon* (Carpio and others 1990) is similar to that of traditional Chinese, Korean, and Japanese SPS noodles (Timmins and others 1992; Wang and others 1995). A major difference is that the processing of SPS noodles normally takes place during winter (5 to 15 °C, 40% to 50% relative humidity (RH)), enabling fast drying of the noodle surface and rapid retrogradation. Under Philippine conditions (27 to 35 °C, 80% to 90% RH), the use of native SPS produces noodles that are very sticky and difficult to handle during processing. Rice flour, MS, and mungbean, are successfully made into starch noodles in the Philippines as these starches retrograde faster. *Bihon* is the most widely consumed noodle type because of its well-accepted texture and reasonable price.

Native SPS of Super Bureau made unacceptable *bihon*-type noodles that were very sticky and when dried adhered to each other even after rehydration and cooking. In a previous study on the production of noodles from native SPS, it was found that higher stability ratio (HPV/CPV) of the RVA viscoamylograph was significantly and highly correlated to hardness of cooked noodles (Collado and Corke 1997). Although some native SPS varieties can be made into noodles the product is generally softer than commercial samples. Noodles from SPS exposed to HMT were not sticky and were comparable to those from maize starch with regard to handling during processing. Starch noodles are essentially retrograded starch (Mestres and others 1988), so starches which retrograde faster (high CPV in their amylographs) are better for noodles.

Noodle cooking time ranged from 2.5 min in 100% SPS to 3.0 min in the other samples. Yield ranged from 75% in 100% HMTSPS and 50:50 HMTSPS: MS to 78% of dry weight of raw starch in 100% MS. Cooking loss ranged from 2.5% for the commercial sample to 4.0% for 100% native SPS. The rehydration rate was lowest with the native SPS noodles at 234% (w/w), and highest for 100% HMTSPS with 262% (w/w). The hardness was highest for 100% HMTSPS with 289 g and lowest for native SP noodles with 156 g, while there were minimal differences in stickiness (ranging from 4.0 to 5.2 g) (Table 2).

## Sensory evaluation

### Raw noodles

Mean sensory attribute scores of raw, plain boiled, and sautéed heat-moisture treated sweet potato starch noodles, 100% MS, and a primera commercial bihon sample is presented in Table 3. Starch noodles with HMTSPS (100% and 50%) had higher color scores and were significantly more yellow than commercial sample and 100% MS. HMTSPS (100%) noodles were significantly less clear than the commercial samples but not significantly different from 100% MS. For both pliability and smoothness, noodles with HMTSPS were not significantly different from the commercial sample and 100% MS samples. It can be noted that, 100% HMTSPS had highest smoothness score and was significantly different from 100% MS. Likewise, acceptability scores of starch noodle samples with HMTSPS were not significantly different from the commercial sample but were significantly higher than 100% MS noodles. Acceptability scores were significantly correlated to pliability but more highly and signifi-

**Table 2—Quality of noodles produced from sweet potato and maize starch**

| | Yield (%) | Cooking Loss (%) | Rehydration (%) | Noodle Texture | |
|---|---|---|---|---|---|
| | | | | Hardness (g) | Stickiness (g) |
| 100% SPS (Native) | 77 | 3.0 | 234 | 156 | 5.2 |
| Commercial noodle | - | 2.5 | 245 | 259 | 5.2 |
| 100% HMTSPS | 75 | 3.0 | 262 | 289 | 5.1 |
| 50:50 HMTSPS:MS | 75 | 2.9 | 259 | 258 | 5.0 |
| 100% Maize | 78 | 2.8 | 249 | 269 | 4.9 |

Each value is a mean of 2 replicate determinations.

**Table 3—Mean sensory attributes scores of raw, plain boiled and sautéed noodles from HMTSPS starch, blend with maize starch maize starch and a commercial *bihon* sample**

| | Commercial Sample | HMTSPS 100% | HMTSPS:MS 50%:50% | MS 100% |
|---|---|---|---|---|
| **Raw Noodles** | | | | |
| Color | 3.17 c | 4.75 a | 4.08 ab | 2.42 d |
| Clarity | 4.42 a | 1.50 c | 2.83 b | 2.33 bc |
| Pliability | 4.33 a | 3.42 abc | 3.17 bc | 2.5 c |
| Smoothness | 2.92 abc | 3.58 a | 3.33 ab | 2.41 bc |
| Acceptability | 2.75 a | 3.50 a | 2.58 a | 2.25 b |
| **Boiled Noodles** | | | | |
| Color | 4.67 a | 4.33 a | 2.92 b | 2.00 c |
| Clarity | 3.83 a | 4.25 a | 2.67 b | 1.67 c |
| Firmness | 3.67 a | 3.08 a | 2.67 a | 3.50 a |
| Flavor | 3.42 a | 3.25 a | 2.92 a | 3.67 a |
| Acceptability | 4.33 a | 3.33 b | 2.83 b | 3.42 ab |
| **Sautéed Noodles** | | | | |
| Color | 1.83 c | 4.08 a | 3.58 b | 2.75 b |
| Clarity | 1.83 c | 3.33 ab | 2.25 bc | 1.67 c |
| Firmness | 2.83 a | 1.67 b | 2.25 ab | 1.83 a |
| Flavor | 2.33 a | 2.25 a | 2.00 a | 2.33 a |
| Acceptability | 2.33 a | 2.25 a | 2.00 a | 2.33 a |

N=12. Sample means for each sensory attribute followed by the same letter are not significantly different at $p < 0.05$.
Range of Scores: Color: 1-white to 5-yellow; Clarity: 1-opaque to 5-clear; Pliability: 1-not pliable to 5-pliable; Smoothness: 1- not smooth to 5-smooth; Firmness: 1-firm to 5-soft; Flavor: 1- characteristic to 5 to not characteristic; Acceptability: 1- very acceptable to 5 to not acceptable

**Table 4—Correlation coefficients of sensory attribute mean scores for raw noodles, boiled noodles, and sautéed noodles from HMTSPS starch, blend with maize starch maize starch and a commercial *bihon* sample**

| Raw Noodles | Color | Clarity | Pliability | Smoothness |
|---|---|---|---|---|
| Clarity | -0.43* | - | | |
| Pliability | 0.25 | -0.38 | - | |
| Smoothness | 0.99* | 0.33 | 0.34 | - |
| Acceptability | 0.85* | -0.38 | 0.42* | 0.82* |
| **Boiled Noodles** | **Color** | **Clarity** | **Firmness** | **Flavor** |
| Clarity | 0.97* | - | | |
| Firmness | 0.19 | 0.00 | - | |
| Flavor | -0.19 | -0.30 | 0.88* | - |
| Acceptability | 0.57* | -0.37 | 0.89* | 0.56* |
| **Sautéed Noodles** | **Color** | **Clarity** | **Firmness** | **Flavor** |
| Clarity | 0.81* | - | | |
| Firmness | -0.71* | -0.53* | - | |
| Flavor | -0.55* | -0.22 | 0.01 | - |
| Acceptability | -0.55* | 0.01 | -0.01 | 0.99* |

N=12. * significant at $p < 0.05$.

**Table 5—Mean intensity scores of liking in selected sensory attributes of sautéed starch noodles as evaluated by untrained panelists**

| | Commercial Sample | HMTSPS 100% | HMTSPS:MS 50%:50% | MS 100% |
|---|---|---|---|---|
| Color | 2.25 a | 2.00 a | 2.25 a | 2.58 a |
| Texture | 2.08 b | 1.42 c | 2.25 b | 3.42 a |
| Flavor | 2.25 b | 1.58 b | 2.17 b | 3.41 a |
| Acceptability | 2.08 b | 1.50 b | 2.00 b | 3.42 a |

N=12. Sample means for each sensory attribute with the same letter are not significantly different at $p < 0.05$.
Range of Scores: 1-like very much to 5-dislike very much.

cantly correlated to color and smoothness scores (Table 4).

### Boiled noodles

In terms of color and clarity, starch noodles with 100% HMTSPS is not significantly different from the commercial sample but is significantly more yellow and clearer than starch noodles with MS (50% and 100%). It is noted that although not significantly different from the commercial *bihon* sample, 100%HMTSPS noodle has highest clarity score. The firmness and flavor scores of the starch noodles evaluated were not significantly different from each other. The acceptability scores of starch noodles with HMTSPS were not significantly different from 100% MS but is significantly different from the commercial sample. Most consumers will not be familiar with plainly boiled noodle quality attributes since noodles are not normally served as such. An evaluation of the sautéed noodles was thus found necessary. Acceptability scores were significantly correlated to color and flavor but more highly and significantly correlated to firmness scores.

### Sautéed starch noodles

Color mean score for 100% HMTSPS noodles was significantly higher than those with MS and the commercial sample. Noodles with HMTSPS were significantly more clear than samples with MS and the commercial *bihon* sample, although in the raw samples, 100% HMTSPS noodles was scored least clear. Clarity of the raw noodles was related to degree of gelatinization/cooking during processing of the noodles (Galvez and others 1994). Processing parameters can still be modified to improve the quality of both raw and cooked noodles. Commercial *bihon* and 100% MS noodles were softer than starch samples with HMTSPS. The flavor and acceptability mean scores of the all starch samples evaluated were not significantly different. Acceptability scores had significant negative correlation with color scores and high positive correlation with flavor scores. In the sensory evaluation of the sautéed starch noodles using untrained housewives, the most liked was 100% HMTSPS, in terms of all the attributes evaluated. The most common reasons cited for the choice were the fuller flavor and distinct chewy texture.

## Conclusions

RESULTS WARRANT FURTHER STUDIES ON OPTIMIZATION OF heat moisture treatment of sweet potato starch and its use in *bihon*-type noodles. Likewise, a consumer testing involving a larger number of noodle consumers with wider background base (age, sex, and preferences) is recommended. Other possibilities in the SP utilization in starch noodles, like *pancit malabon* (a noodle with a bigger dia and cooked with a different sauce), should be explored. Still other possibilities include the use of additives and of blends with other locally produced starches to determine their comparative advantage to the use of HMT to modify SPS for use in noodle production.

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*Authors Collado and Mabesa are with the Institute of Food Science and Technology, Univ of the Philippines at Los Baños, College, Laguna 4031, Philippines. Author Oates is with Argo Food Resources (Thailand) Co. Ltd., Rattanatibet Road, Nonthaburi, Thailand. Author Corke is with the Cereal Science Laboratory, Dept of Botany, The University of Hong Kong, Pokfulam Road, Hong Kong. Direct inquiries to Harold Corke (E-mail: harold@hku.hk).*