Cooking Characteristics and Quality of Noodles from Food Sorghum

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ABSTRACT

Three white food sorghums, ATx631*RTx436, ATxARG*RTx436, and SC283-14, were decorticated, milled into flour and processed into 100% sorghum noodles. Flour, water, and salt (1%) were preheated using a hot-plate or a microwave oven. The mixtures were put through a forming extruder to produce noodles. Extruded noodles were dried by three methods: air-dry method (23°C, 48 hr); one-stage (60°C, 30% rh, 3 hr), or two-stage (60°C, 100% rh for 2 hr followed by 60°C, 30% rh for 2 hr). Noodles were evaluated dry and after cooking. Sorghum flours with smaller particle sizes yielded better noodles. The microwave preheating method yielded better noodles than the hot-plate method. Stronger and firmer noodles, dry or cooked, were prepared using two-stage drying compared with the other drying methods. Fine flour that was preheated using a microwave oven and dried using the two-stage method gave the best noodles with moderate (10%) dry matter loss. Optimized processing conditions yielded sorghum noodles with good qualities when properly cooked.

Sorghum (*Sorghum bicolor*) is grown in the semi-arid tropics for human food (Serna-Saldivar et al 1991). Preparation of traditional sorghum foods is laborious and time-consuming. Urban consumers have less time and desire to prepare traditional sorghum foods, as evidenced by the rapid increase in consumption of more expensive, imported, preprocessed, cereal foods (e.g., decorticated rice, pasta, and bread). Therefore, for sorghum to be competitive with imported cereal foods, preprocessed or alternative sorghum-based foods are required.

Pasta made from wheat utilizes proteins to strengthen and retain the integrity of dry, cooked products and to reduce cooking losses. Nonwheat noodles (e.g., rice, mung bean, and sweet potato noodles) utilize starch instead of protein to enhance their structure. Cooked starch-based noodles usually have a clear appearance and highly elastic rubbery texture (Xu and Seib 1993, Kohlway et al 1995). Cooked flour-based noodles are less firm, less rubbery, and more opaque than starch-based noodles (H. Corke, *personal communication*). Ingredients and processes that promote dispersion and retrogradation of amylose produced maize flour-based noodles with lower cooking losses (Mestres et al 1993). Waniska et al (1999) utilized a home-style pasta extruder to prepare maize-flour noodles from preheated flour and water; however, preparation and drying conditions were not optimized.

The objectives of this study were to determine factors that affect the quality of sorghum-flour noodles.

MATERIALS AND METHODS

Raw Materials

Sorghums ATx631*RTx436 (food-type, nonwaxy), ATxARG1*-Tx436 (food-type, heterowaxy), and SC-283-14 (hard endosperm) were grown under irrigation at the Texas A&M Experiment Station at Halfway, TX, in 1992. Sorghums were cleaned and stored in a freezer before use. Commercial sorghum flour (Jowar Foods, Inc., Hereford, TX) was also used.

Sorghum Flour Preparation

Sorghums were decorticated with an abrasive dehuller (PRL Mini-Dehuller, Nutana Machine Co., Saskatoon, Canada) until 10% of the pericarp was removed. The decorticating was controlled by monitoring the weight of decorticated sorghum. The decorticated sorghums were milled into flour using the break and reduction roll system of the Brabender Quadrumat Senior Mill (C.W. Brabender Instruments, Inc., South Hackensack, NJ).

In addition, a two-step process was used to mill ATx631*RTx436. Decorticated sorghum was hammer-milled (Fitz mill model D, Fitzpatrick Co., Elmhurst, IL) using screens with 1-mm openings. This flour was further reduced using the reduction rolls and sieves of the Quadrumat Senior Mill.

Noodle Preparation

Methods for producing noodles from sorghum flour were modified from Waniska and coworkers (1999) (Fig. 1). A flour-water mixture was prepared by gradually adding distilled water (90 mL) to sorghum flour (100 g) with 1% salt while mixing with a rubber spatula. The flour-water mixture was heated using a hot-plate or a microwave oven. For the hot-plate method, the mixture was heated in a Pyrex skillet (Corning Glass Works Co., Corning, NY) on a laboratory hot-plate (PC-320, Corning). The mixture was continuously stirred for 5 min at 80°C. For the microwave method, the flour, water, and salt were mixed in a 1-qt glass jar. The mixture was pressed along the side and bottom of the jar to ensure uniform heating. The mixture was heated on high power for 1.5 min to 95°C. The mixture was stirred every 40 sec in a microwave oven (Kenmore model 721.89660590, Sears Roebuck and Co., Hoffman Estates, IL).

The preheated mixture was passed through a forming extruder to produce noodles (mixer model N-50, Hobart Manufacturing Co., Troy, OH, with a pasta attachment, model K5-A, KitchenAid, St. Joseph, MI, using a pasta die with 1.7 mm diameter holes). The noodles were reextruded two more times for a total of three passes through the forming extruder. This was done to assure complete mixing of the preheated dough by the forming screw.

Sorghum Noodle Drying Methods

Extruded noodles were separated and placed on metal trays lined with paper liners. Noodles were dried by three methods: slow (air-dried), one-stage (rapid-hot/low-humidity) or two-stage (rapid-hot/high-humidity). Extrudates were air-dried at room temperature (25°C, 60% rh) for 48 hr in the slow method. In the one-step or rapid-hot/low-humidity method, extrudates were placed in a proof chamber (National Manufacturing Co., Lincoln, NE) at 60°C and 30% rh for 3 hr. In the two-step or rapid-hot/high-humidity method, extrudates were placed in a proof chamber at 60°C, 100% rh for 2 hr followed by 2 hr at 60°C, 30% rh. Dried noodles were wrapped in plastic and double bagged in plastic bags before being stored at –18°C.

Analytical Methods

The one-stage Approved Method 44-16 (AACC 1995) was used to determine the moisture content of raw materials and noodles. Particle size of flour was determined (Gomez 1988). Color was determined using a colorimeter (CR-310, Minolta Co.). Organic nitrogen was determined using conversion factors of 6.25 for

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sorghum and corn, 5.7 for wheat, and 5.95 for rice. Starch was determined using AACC Approved Method 17-13. Pasting properties of dried, uncooked noodles were measured using a pasting viscometer (RVA-3C, Newport Scientific, Warriewood, NSW, Australia). The time (min) and temperature (°C) profile was 0:50, 2:50, 6.5:95, 11:95, 15:95, and 18:95. The diameter of noodles was measured using calipers.

Uncooked noodles were subjectively evaluated by a trained personnel for surface smoothness, overall appearance, quality, and hardness. The quality of the noodles was rated using a scale of 1 (low value, worst) through 5 (high value, best). Noodle hardness was subjectively rated by breaking a 2-cm piece between the index and ring fingers with the thumb. Samples were rated 1 (easily fractured) through 5 (hard to fracture).

Optimum cooking time was the time required for the opaque central core of the noodle to disappear when squeezed gently between two glass plates (Approved Method 16-50, AACC 1995). Water uptake and dry matter losses during cooking were determined by AACC Approved Method 16-50. Noodles (10 g) were cooked to optimum time in 300 mL of distilled water in a beaker, rinsed in cold water and drained for 15 min before being weighed. Solids content in the water was determined by drying overnight at 105°C.

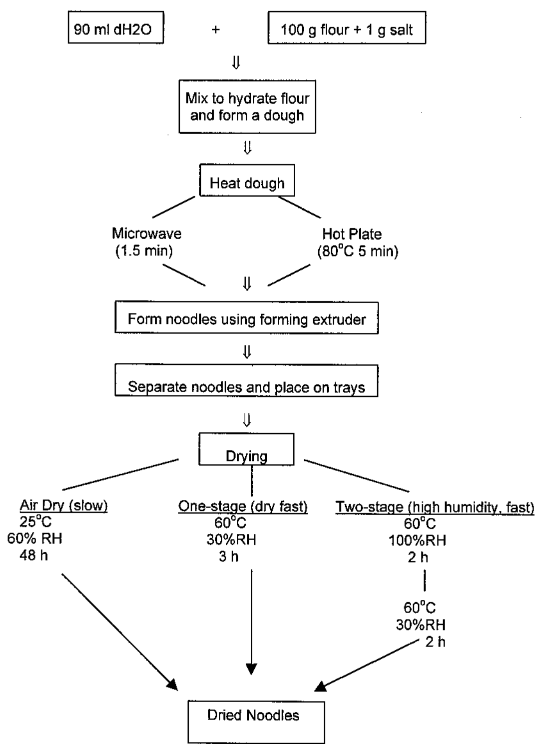

Fig. 1. Noodle production process.

A trained panelist subjectively rated cooked noodles for firmness, adhesiveness, chewiness, and overall acceptability using a scale of 1 (low) to 5 (high).

Firmness of the cooked noodles was measured by Approved Method 16-50 (AACC 1995) for pasta with modifications. A stainless steel cylindrical probe (5 cm diameter) was used to compress cooked noodles. Peak force as firmness (N), adhesion as a negative force, area under the negative peak force curve, and final force after 10 sec of compression was recorded using the TA.XT2 texture analyzer (Stable Micro Systems, Texture Technology Corp., Scarsdale, NY). Based on preliminary trials, test parameters were set as pretest speed = 10 mm/sec; test speed = 10 mm/sec; and post test speed = 10 mm/sec; distance = 0.5 mm; time = 10 sec; trigger force = 0.1 N.

RESULTS AND DISCUSSION

Characterization of Flours

The sorghum cultivar affected flour particle size (Fig. 2). SC283-14E had the hardest endosperm texture (Table I) and produced flour with smallest particles during roller milling (Fig. 2). Jowar (commercial, hammer-milled) and ATxARG1*RTx436 (roller-milled) had the coarsest flours. The hard endosperm of the SC283-14E cultivar caused the kernel to fracture differently at the break rolls, possibly into fine particles, that broke across the endosperm cells and released starch, while others were fractured along endosperm cell walls, creating larger chunks. Similar results were reported by Murty and coworkers (1981, 1984).

The combined, two-step milling process (hammer and roller mills) produced finer flour than using the roller mill alone (Fig. 2). The yield of the flour attained from the roller milling procedure was 60 ± 2%. Leon-Chapa et al (1998) produced similar flour yields using the roller mill process.

Cultivar and particle size affected the pasting properties of sorghum flour (Fig. 3). Flour from ATx631*RTx436 had higher peak

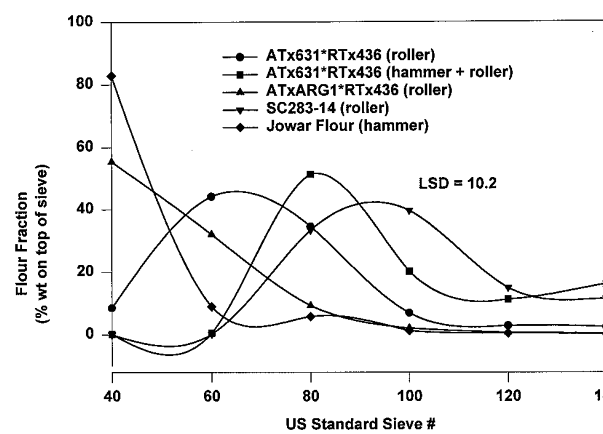

Fig. 2. Particle-size distribution of flours used in noodle production.

TABLE I
Characteristics of Flours Used for Noodle Production

Sample	Milling Method	Moisture (%)	Protein (db %)	Starch (db %)	Amylose (%)	Hardness (%)[a]	Color *L**	Color *a**	Color *b**
ATx631*RTx436	Roller[b]	13.3	8.7	81.0	31.7	30.4	89.4	–1.7	9.5
ATx631*RTx436	Hammer + Roller[c]	13.5	8.3	79.4	31.7	30.4	84.4	2.1	9.6
ATxARG1*RTx436	Roller[b]	12.4	7.3	75.6	24.2	23.4	81.6	2.3	10.9
SC283-14E	Roller[b]	14.7	8.9	79.8	25.2	14.0	85.4	0.1	8.0
Sorghum	Commercial[d]	12.9	10.1	75.2	· · ·	· · ·	81.4	0.1	13.7
LSD[e]		0.9	0.1	3.5	· · ·	0.5	0.8	0.2	0.3

[a] Hardness, expressed as % removal by abrasive dehuller. Lower % removal indicates harder kernel, higher % removal indicates softer kernels.
[b] Sorghum milled using break and reduction roller mill.
[c] Sorghum milled using a hammer mill then a reduction roller mill.
[d] Jowar Foods, Inc., Hereford, TX.
[e] Least significant difference ($P < 0.05$)

viscosity than the other cultivars and earlier viscosity development than Jowar or ATxARG1*RTx436. Sorghum flours with larger particle sizes (Jowar and ATxARG1*RTx436) had lower pasting viscosities and later viscosity development. Development of pasting viscosity occurred ≈10°C earlier for finer flours than for coarser flours (Fig. 3). The harder endosperm sorghum (SC283-14E) produced finer flour, which probably caused the more rapid development of viscosity.

Effects of Preheating and Drying Methods

Both preheating and drying methods affected noodles prepared from roller-milled ATx631*Tx436 flour (Table II). Air-dried and one-stage dried noodles were curved, while noodles dried by the two-stage method remained straight (Table II). Shear stress during extrusion (i.e., nonuniform pressure on dough going through the die contributed to the distortion of the noodle), drying method, or the rate of removal of water were also involved.

Dry and cooked noodles were harder and firmer (i.e., required more force and work to rupture) when prepared using the microwave oven compared with the hot-plate method. Noodles prepared using the microwave method had lower water uptake and dry matter losses compared with noodles prepared using the hot-plate method.

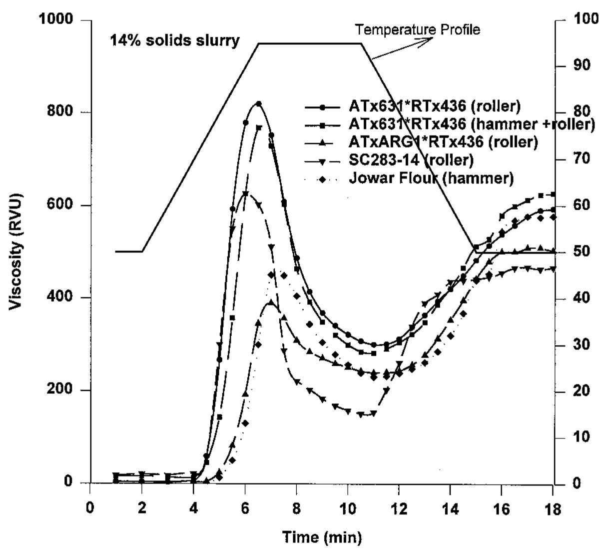

Fig. 3. Pasting characteristics of sorghum flours used for noodle production.

Starch was partially gelatinized and partially dispersed during preheating by both heating methods. The initial pasting viscosity of flour prepared from dry noodles indicates the presence of gelatinized starch. Fernandez and coworkers (1999) demonstrated that lower initial pasting viscosity and later development of viscosity indicate that more starch had gelatinized and retrograded during processing. Because noodles prepared using the hot-plate method had lower peak viscosity and later viscosity development (Fig. 4), noodles prepared using the hot-plate method had more starch gelatinization and more starch retrogradation compared with noodles prepared in the microwave method. The shorter time the flour was at >65°C in the microwave method may have decreased the modification of starch.

The drying procedure affected the quality of sorghum noodles (Table II). Cooked noodles were chewier when prepared using the air or one-stage drying method compared with those prepared using the two-stage drying method. Higher initial pasting viscosities were observed in noodles rapidly dried using the one-stage drying method (Fig. 4). This corresponds to more gelatinized but less retrograded starch. Rapid drying using hot-dry conditions shortens the period that amylose is mobile, reducing retrogradation. Low initial viscosity and delayed viscosity development were observed in noodles dried using the two-stage drying method. The hot-moist drying period enhances amylose mobility and chain reassociation while moisture was present (Mestres et al 1993). Amylopectin presumably was melted (i.e., in a mobile state during the hot-high humidity drying period).

The longer, air-dry method caused pasting curves of noodles prepared using the microwave and hot-plate methods to respond differently (Fig. 5). Air-dried noodles prepared using the microwave method had high initial viscosity, slightly delayed viscosity development, and high peak viscosity, whereas noodles prepared using the hot-plate method had low initial viscosity and significantly delayed viscosity development. Better dry and cooked noodle properties (firmer, less chewy, less sticky noodles with low dry matter losses) were observed when prepared using the microwave preheated flour and high humidity-fast drying methods.

TABLE II
Effects of Preheating and Drying Methods on Properties of Sorghum Noodles Prepared from ATx631*RTx436

Property	Hot-Plate Air-Dry	Hot-Plate One-Stage	Hot-Plate Two-Stage	Microwave Air-Dry	Microwave One-Stage	Microwave Two-Stage	LSD[a]
Properties of dry noodles							
Hardness[b]	3.0	2.5	3.0	4.0	3.8	4.5	0.6
Smoothness[b]	2.0	2.5	2.0	2.0	3.0	4.0	0.5
Color	White	White	White	White	White	White	
Geometry	Round, curved	Oval, curved	Round, straight	Round, curved	Oval, curved	Round, straight	
Acceptability[b]	3.0	3.0	4.0	3.0	3.0	4.0	0.5
Moisture (%)	10.7	7.4	8.1	11.4	8.4	10.7	0.48
Pasting properties of dry noodles							
Peak viscosity (RVU)	243	267	289	328	252	354	13
Peak time (min)	8.25	7.97	6.45	3.54	4.30	5.85	2.37
Temperature (°C, 100 RVU)	88	50	70	50	50	60	1.5
Properties of cooked noodles							
Cook time (min)	4.0	4.5	5.5	5.2	4.5	5.5	0.35
Dry matter loss (%)	23.6	20.8	23.7	10.7	18.9	9.2	1.44
Water uptake (%)	241	225	263	192	187	193	4.4
Firmness[b]	2	2	3	4	4	4	0.6
Chewiness[b]	4	4	3	4	4	2	0.7
Stickiness[b]	4	2	2	1	1	2	0.5
Acceptability[b]	3.5	3.0	3.5	3.0	4.0	4.0	0.7
Compression force (N)	10.5	7.3	13.1	18.7	12.3	20.5	1.7
Final force (N)	4.8	3.2	5.6	8.2	5.7	8.3	1.2
Adhesion (N × mm)	–0.6	–0.5	–1.3	–2.4	–1.0	–2.1	1.0

[a] Least significant difference ($P < 0.05$).
[b] Subjective evaluation scale: 1 = low (easy to break) to 5 = high (hard to break).

Effect of Particle Size

The effect of particle size on noodle quality was evaluated on noodles made from ATx631*RTx436 flour milled by two different milling methods using two-step drying procedure. The combination roller and hammer milling method produced sorghum flour with smaller particle size than flour produced by roller milling method alone.

Acceptability of noodles made from roller milling alone and those from a combination of roller and hammer milling methods were similar. However, noodles made from the two-step milling (roller and hammer) method had slightly higher water uptake compared with those made from roller milling alone (Table III).

Initial viscosity of dry noodles prepared from smaller particle size sorghum flour (two-step milling) was higher than those prepared from coarser flour (roller milling) (Fig. 5). Peak viscosities of the ATx631*RTx436 flour produced from the two different milling methods were similar. As discussed earlier, higher initial viscosity indicates that starch in noodles prepared from finer flour was more gelatinized than that from coarser flour. The higher water absorption of noodles produced from finer flour supports its increased gelatinization.

Effect of Sorghum Cultivar

Sorghum noodles from different cultivars was produced using the two-step drying procedure. Good quality noodles with low dry matter losses were prepared from the finer flours (SC283-14E and ATx631*RTx436) using two-step milling. Dry noodles made from coarse flour (Jowar and ATxARG1*RTx436) were fragile, had rough surfaces, high dry matter losses during cooking, and softer cooked noodles (Table III).

Noodles made from heterowaxy sorghum (ATxARG1*RTx436) flour were significantly stickier and softer than the other noodles, as indicated by low compression and high adhesion forces.

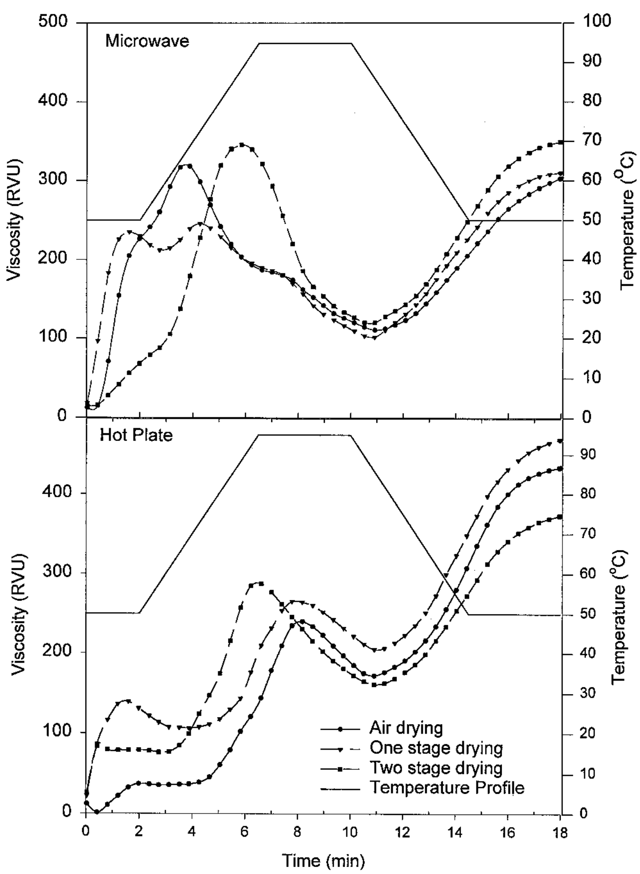

Fig. 4. Effect of heating and drying method on pasting characteristics of uncooked sorghum noodles. ATX631*RTx436 (roller milled, 14% solids).

The increased amylopectin and reduced amylose in the heterowaxy flour (Table I) modified the rate and extent of retrogradation in noodles as reported in stiff porridges (Bello et al 1995) and in corn tortillas (Quintero-Fuentes 1999). The starch was gelatinized, as seen in the pasting curve, but retrogradation was limited, leading to high dry matter losses in the cooked product.

Initial viscosities of dry noodles prepared from small particle size sorghum flours (SC283-14E and ATx631*RTx436) using two-step milling were higher than those prepared from coarser flour. The high initial viscosity and peak viscosity indicate that more starch has been gelatinized and sufficient retrogradation occurred to provide structural stability of dry and cooked noodles prepared from small particle size flour. Correspondingly, noodles prepared from flours with larger particle size (Jowar and ATxARG1*RTx436) had lower pasting viscosities that developed later during the heating cycle. The integrity of the larger flour particles delayed gelatinization and dispersion of starch during noodle processing and during analysis of pasting properties of the dried noodles.

SUMMARY

Flour particle size significantly affects nonwheat noodle quality. Finer flour produces better quality nonwheat noodles. Nonwheat noodles utilize starch gelatinization to enhance their structure. The microwave method produces better quality noodles than the hot plate method. High-heat, high-humidity (two-stage) drying improved the quality of sorghum noodles processed using the microwave method.

The sequence and timing of starch gelatinization and retrogradation significantly affected noodle characteristics. The more rapid heating method yielded partially gelatinized starch that did not have time to retrograde before processing into noodles. Hence, the timing of the dispersion of amylose, formation of noodles, and amylose retrogradation is critical. Optimization of amylose functionality should yield significantly improved starch-based foods. For example, large-scale production of sorghum noodles could be achieved using steam pretreatment immediately before processing into noodles, followed by a steam-chamber retrogradation period and air-drying.

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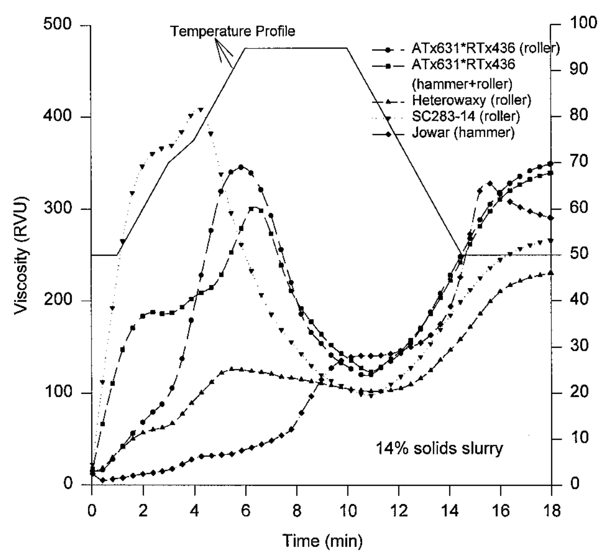

Fig. 5. Pasting characteristics of uncooked noodles made from different sorghum flours using two-stage (high humidity, high temperature) drying method.

TABLE III
Properties of Dry and Cooked Noodles Prepared Using Different Sorghum Flours

	ATx631*RTx436 Roller	ATx631*RTx436 Hammer + Roller	ATxARG1*RTx436 Roller	SC283-14 Roller	Jowar Hammer	LSD[a]
Pasting properties of flour						
Peak viscosity (RVU)	810	753	671	633	456	20.9
Peak time (min)	6.42	6.69	6.97	6.12	7.25	0.17
Properties of dry noodles[b]						
Hardness[c]	4.5	3.5	2.8	4.6	1.0	0.6
Smoothness[c]	4.0	3.8	2.5	4.2	1.4	0.5
Color	Off-white	Off-white	Tan	Off-white	Brown	
Geometry	Compact	Compact	Internal fissure	Compact	External/internal fissure	
Moisture (%)	10.7	11.4	9.8	10.2	10.2	0.4
Acceptability[c]	4.0	4.0	2.5	4.0	2.0	0.5
Pasting properties of dry noodles						
Peak viscosity (RVU)	354.3	303.5	123.4	410.4	141.3	22.9
Peak time (min)	5.85	6.35	5.48	4.20	10.58	0.61
Temperature (°C, 100 RVU)	76	50	71	50	95	1.5
Properties of cooked noodles						
Cook time (min)	5.5	5.2	4.2	6.0	3.2	0.7
Dry matter loss (%)	9.2	11.9	32.9	11.9	13.5	0.6
Water uptake (%)	193	205	209	112	124	7.6
Firmness[c]	4	3.8	2.5	4	1	0.6
Chewiness[c]	2	2	4	2.5	1	0.7
Stickiness[c]	2	2	4	2	1	0.5
Taste	Bland	Bland	Earthy	Bland	Earthy, grainy	
Acceptability[c]	4	4	2.8	4	1	
Compression force (N)	20.5	19.3	10.8	24.6	4.1	1.8
Final force (N)	8.3	9.3	3.0	14.1	1.7	1.2
Adhesion (N × mm)	–2.1	–1.5	–2.3	–1.4	–0.3	0.6

[a] Least significant difference ($P < 0.05$).
[b] Microwave preheating method and two-stage drying method (high temperature, high humidity).
[c] Subjective evaluation scale: 1 = low to 5 = high.

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