Physicochemical Properties of Flours that Relate to Sorghum Couscous Quality[1]

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ABSTRACT

Flours from eight sorghum cultivars were evaluated for their couscous-making ability with the objective of finding predictive relationships between flour physicochemical properties and couscous quality. Chemical composition, physical characteristics, and pasting and gelatinization properties of the flours were determined. A laboratory procedure was used to prepare couscous. Couscous properties were evaluated and compared to a laboratory-prepared and a commercial durum wheat couscous. Hard grain produced flours containing a high proportion of coarse particles with low ash and high damaged starch content and yielded a higher proportion of desirable sorghum couscous granules. A variety of colors ranging from brown to yellow were obtained when flours were processed into couscous. Cooked sorghum couscous stickiness was positively correlated ($r = 0.89$, $P < 0.01$) with the amount of damaged starch in flour. Cooked couscous hardness correlated positively ($r = 0.79$, $P < 0.05$) with apparent amylose content of flour and correlated negatively ($r = -0.75$, $P < 0.05$) with flour peak viscosity. Durum wheat couscous was lighter and had more yellow color than sorghum couscous. Sorghum couscous was stickier and harder than durum wheat couscous. Addition of 2% oil to the cooking water considerably improved the texture of some sorghum couscous to a level comparable to that of durum wheat couscous.

Couscous is a very popular food product in many African countries. In North Africa, couscous is made from durum wheat semolina (Kaup and Walker 1986), whereas in West Africa, sorghum, millet, maize, or fonio flours are used (Galiba et al 1987). Couscous is prepared by mixing flour with water, agglomerating the flour-water mixture into small granules, steaming, and drying. Couscous is consumed with milk for breakfast or with a vegetable or meat sauce for lunch or dinner. In West Africa, couscous is traditionally prepared in the household, and sorghum or millet couscous is rarely available commercially in either urban or rural markets. In contrast, imported wheat couscous is readily available, particularly in urban centers. In many West African countries, several attempts are now being made to develop small-scale processing units for the commercial production of sorghum, millet, and maize couscous (*personal communications*).

Sorghum cultivars differ in their couscous-making ability (Sidibe et al 1982). Couscous quality criteria include yield, size uniformity, color, stickiness, and mouthfeel (Sidibe et al 1982, Debbouz and Donnelly 1996). According to Kaup and Walker (1986), good quality couscous should absorb sauce well and must have uniform particles that do not stick to one another nor lose their integrity when steam or sauce is applied. Galiba et al (1988) investigated the relationship between kernel characteristics and couscous quality of eight sorghum cultivars. They reported that endosperm texture and type affected sorghum couscous yield and color. The authors also found that sorghum with corneous endosperm texture (nonwaxy endosperm type), thin white pericarp, and tan secondary plant color made the best couscous product. To date, there have been no published investigations on the relationship between sorghum flour properties and couscous quality. The cooking properties of cereal starches and flours can be generally studied using the Brabender Visco-Amylograph and differential scanning calorimetry (DSC). Using amylography, Juliano et al (1985) and Ong and Blanshard (1995) showed that the hardness of cooked rice was positively correlated with flour paste viscosity breakdown, hot and cold paste viscosities, and setback values. Paste viscosity of noodle flours was found to correlate with the cooking quality of Japanese-type noodles (Bean et al 1974). Shuey and Gilles (1964) also reported that the pasting characteristics of semolina from three cultivars of durum wheat were associated with the texture of cooked macaroni. Ong and Blanshard (1995) used DSC to measure the enthalpies and temperatures of gelatinization of 11 rice cultivars and reported that the enthalpies, but not the gelatinization temperatures, correlated with cooked rice hardness.

The objective of this study was to determine the flour properties that affect sorghum couscous yield, color, and texture. These properties could then be used to establish flour quality standards for the production of a good quality couscous product that could succeed in West African urban markets. An additional objective was to compare couscous made from different sorghum cultivars to durum wheat couscous.

MATERIALS AND METHODS

Materials

Eight sorghum cultivars grown in West Lafayette, IN, during the 1994 crop season were used. The cultivars, all used for food preparation, were selected on the basis of differences in endosperm texture (hardness) and were type I, white sorghum phenotypes. They included a Nigerien landrace variety (Mota Maradi) and four improved cultivars (IRAT-204, SC283-10, NAD-1, and SEPON) currently grown and used in Niger. A high-lysine mutant (P721Q), along with its parent (P721N), and a highly digestible, high-lysine cultivar (P851171) derived from P721Q, were also included. Grains were decorticated by abrasion in a laboratory decorticator (Natana Machine Ltd., Saskatoon, Canada). Each sample was milled several times until a decortication rate of ≈80 % was obtained. Decortication time was determined by trial and error. A pin mill (model 160 Z, Alpine, Ausburg, Germany) operating at 14,000 rpm was used to grind the decorticated grain into flour.

Physical and Chemical Analyses

Grain hardness was measured by the Stenvert hardness test (Pomeranz et al 1985). In this test, a 20-g grain sample was ground in a micro hammer-cutter mill (Glen Mills Inc., Maywood, NJ) and the time (sec) to collect 17 mL of ground meal was reported as Stenvert hardness. Higher values indicate harder grain. Flour particle-size distribution was determined by air-sifting 20 g of flour for 3 min on an air jet sieve (Alpine, Natick, MA) using U.S. no. 60 (250 µm openings) and U.S. no. 120 (125 µm openings) sieves. Flour was separated into fine (<125 µm), intermediate (125–250 µm), and coarse (>250 µm) fractions.

Moisture, ash, and protein contents of the flours were determined according to Approved Methods (AACC 1995). Protein fractions were quantified using the Wallace et al (1990) method as modified by Hamaker et al (1995).

Total starch was estimated by AACC Approved Method 76-12 using the Megazyme Kit (Megazyme, Australia). The procedure described by Landers et al (1991) was used to determine the apparent

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amylose content of the flours. Damaged starch in flour was estimated using α-amylase as described by Barnes (1978).

Pasting Properties of Sorghum Flours

Pasting properties of flour were measured with a Brabender Visco-Amylograph using AACC Approved Method 61-01 for rice flour. The pasting temperature, peak viscosity, hot paste viscosity, and cold paste viscosity were directly obtained from the pasting curve. Some additional parameters such as breakdown (peak viscosity minus hot paste viscosity), setback (cold paste viscosity minus hot paste viscosity) and consistency (cold paste viscosity minus peak viscosity) were also calculated.

Thermal Properties of Sorghum Flours

A differential scanning calorimeter equipped with an evaluation and control center (DSC-30, TC11 TA, Mettler, Hightstown, NJ) was used to determine the thermal properties of the flours. Flour-to-water mixtures (1:2, w/w) were hermetically sealed in a DSC aluminum pan and heated from 25 to 100°C at a rate of 10°C/min. An empty pan was used as reference. The onset, peak, and conclusion gelatinization temperatures and enthalpy were obtained from the heating curve.

Couscous Preparation

For each sorghum cultivar, 200 g of flour was hand-mixed with 125 mL of water to obtain a homogeneous mixture. The mixture was then pressed through a 1.5-mm sieve to form agglomerated flour particles (Galiba et al 1987). Laboratory durum wheat couscous was prepared by hand-mixing semolina with water until agglomerated flour particles were formed (Debbouz et al 1994). The particles were spread on a cheese-cloth and steamed in a couscoussier (steamer) for 15 min with mixing at 5-min intervals. The precooked couscous was dried at 50°C for 16 hr in an air oven and sieved using a Ro-Tap testing shaker (W. S. Tyler Co., Cleveland, OH) to separate couscous particles into fine (<1 mm), intermediate (1–2 mm), and coarse particles (>2 mm). For each cultivar, couscous was prepared in two replicates from the same batch of flour. Yield measurements were made on each replicate. Commercial durum wheat couscous was purchased from a local market in West Lafayette, IN.

Couscous Color, Water Absorption Index, and Water Solubility Index

Flour and couscous colors were measured with a Hunter Lab colorimeter. Color was described in terms of lightness (L), redness (a) and yellowness (b). In Lab units, L indicates lightness, a(+) indicates red, a(–) indicates green, b(+) indicates yellow, and b(–) indicates blue. The greater the L, a, and b values, the lighter, the more red, and the more yellow the samples, respectively. Couscous water absorption index (WAI) and water solubility index (WSI) were determined by the method of Anderson et al (1969). Measurements were made in duplicate.

Couscous Texture

The textural characteristics of couscous were determined by texture profile analysis (TPA) using a TA-XT2 texture analyzer (Texture Technologies Corp., Scarsdale, NY). A 10-g sample of couscous was transferred into a 50-mL beaker containing 10 mL of boiling water and cooked under low heat for 5 min. The cooked couscous was immediately transferred to a plastic bag and sealed. Couscous was allowed to cool to room temperature for 10 min. Oil effect on couscous texture was evaluated after addition of 2% pure soybean oil (Crisco oil, Procter and Gamble, Cincinnati, OH) to the boiling water. For texture analysis, cooked couscous (2 g) was transferred into a molded nalgene polypropylene tube (15-mm height) which was placed in a fixture to hold it in place under the texture analyzer. A TA circular acrylic cylinder probe was used to compress the couscous sample to 50% of its original height at a speed of 1.0 mm/sec. A two-stroke (double compression) test was used with a programmed 5-sec wait between strokes. The parameters obtained from TPA included springiness, cohesiveness, hardness, adhesiveness (stickiness), chewiness (hardness × springiness × cohesiveness), and gumminess (cohesiveness × hardness). Three parameters (hardness, adhesiveness, and chewiness) were used to describe couscous texture. For each cultivar, four measurements were taken.

Statistical Analysis

Results from the various experiments were analyzed by the analysis of variance procedure, and the significance of differences among cultivars was determined using Duncan's method of multiple comparison. The relationships between the parameters were evaluated by Pearson correlation coefficients. All statistical procedures were performed using SAS methods (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Physical Properties of Grain and Flour

Grain hardness, or endosperm texture, has been considered to be the single most important characteristic in determining the general food-making quality of sorghum grain (Rooney et al 1986). As shown in Table I, sorghum cultivars used in this study had a wide range of hardness values (12.8–35.0 sec). Flours produced from these grains had significant cultivar differences in their particle-size distribution. The hardest cultivars (SC283-10 and NAD-1) produced the highest proportion of the coarse flour fraction (Table I). The softer cultivars produced higher amounts of the fine flour fraction, though Mota Maradi also had a relatively high amount of coarse particles.

Chemical Composition of Flour

Flour ash content varied from 0.60% for SC283-10 to 1.31% for P721Q; total protein content ranged from 8.7% for NAD-1 to 12.6% for Mota Maradi (Table II). Albumins and globulins content (plus nonprotein nitrogen) was highest in P721Q and P851171 (14.9 and 16.4% of total protein, respectively), which is related to their high lysine content (Ejeta and Axtell 1987). Based on total protein, kafirin concentration was highest in NAD-1 (81.3%) and lowest in high lysine cultivars P851171 and P721Q (70.5 and 71.8%, respectively). The remaining protein was composed of glutelins that ranged from 9.1% for NAD-1 to 21.5% for IRAT-204.

Total starch, apparent amylose, and damaged starch content among flours were significantly different at 78.5–89%, 18.6–22.5%, and 3.2–7.2%, respectively (Table II).

Amylograph Pasting Properties of Sorghum Flours

Cooking properties of sorghum flours in excess water were investigated with the Brabender amylograph. Significant differences in all the pasting parameters were observed among the sorghum cultivars (Table III). The pasting temperatures of the flours fell into

TABLE I
Grain Hardness and Particle-Size Distribution of Decorticated Sorghum Flours

Cultivar	Stenvert Hardness[a] (sec)	Flour Particle-Size Distribution (%)		
		<125 μm	125–250 μm	>250 μm
SC283-10	35.0a[b]	24.4h	16.2cd	59.4a
NAD-1	25.7b	31.6g	15.9b	52.5b
P721N	23.3c	36.4e	17.0a	46.7d
IRAT-204	23.2c	35.5f	14.7c	49.8c
P851171	21.1d	68.9b	16.8ab	14.3f
SEPON	20.7d	38.6d	14.3d	47.1d
P721Q	17.9e	71.9a	16.3b	11.9g
Mota Maradi	12.8f	43.3c	14.8c	42.0e

[a] Higher values indicate harder grain.
[b] Means followed by the same letter in each column are not significantly different ($P < 0.05$).

two groups. Cultivars SC283-10, NAD-1, IRAT-204, and P851171 had a pasting temperature of 80°C, while Mota Maradi, P721N, P721Q, and SEPON had a pasting temperature of 83°C. These results agree with those reported by Akingbala and Rooney (1987), who found an average pasting temperature of 81.2°C for flour from non-waxy sorghum cultivars. Peak paste viscosity ranged from 335 BU for Mota Maradi to 505 BU for NAD-1. Apparent amylose content was associated with peak viscosity ($r = -0.82$, $P < 0.05$).

Thermal Properties of Sorghum Flours

Gelatinization of flours in limited water and under no shear were investigated using DSC. Table IV lists the gelatinization temperatures (onset, peak, and conclusion) and heat of gelatinization (enthalpy, ΔH) of the flours. Heat of gelatinization was highest for P721Q and P851171 (ΔH = 7.8 and 7.2 J/g, respectively), which also had the lowest amount of damaged starch, the highest proportion of fine flour fraction, and the highest ash content in their flours. Cultivars NAD-1, P721N, SEPON, and SC283-10 required 6.1, 5.9, 5.7, and 5.1 J/g, respectively, to gelatinize. The lowest ΔH was obtained with IRAT-204 (4.5 J/g) and Mota Maradi (4.4 J/g). Differences in thermal properties among sorghum cultivars suggest varietal differences in cooking time and heat requirement for the flours.

Particle-Size Distribution of Sorghum Couscous

Table V shows the particle-size distribution of sorghum couscous after steaming and drying. Dried couscous material passing through the small sieve (<1 mm) and overs remaining on the large sieve (>2 mm) were not considered to be couscous and were not used in further analyses. The percentage of couscous of 1–2 mm diameter was highest for SC283-10 (68%) and IRAT 204-10 (67%). The lowest percentages were obtained with P721Q (44%) and P851171 (47%), which yielded higher proportion of small (<1 mm) undesirable couscous granules (Table V). These two cultivars also had the highest ash content and highest proportion of fine flour fraction. Since ash is often used as an indicator of the presence of bran in flour, the low yield of desirable couscous particles from these cultivars may be due to competition for water between starch and bran, resulting in less water available for starch gelatinization during couscous manufacture. Debbouz et al (1994) reported that durum wheat flour with high proportion of intermediate and coarse particles yielded more couscous.

Couscous Color

Sorghum couscous lightness and yellowness ranged from 47.1 for P721Q to 56.3 for SEPON, and from 11.3 for SC283-10 to 18.7 for SEPON, respectively (Table V). Red color in sorghum couscous ranged from 1.2 for SEPON to 7.3 for P721Q. In general, these values for sorghum are in agreement with those (52.3–65.3 for lightness and 12.2–18.1 for yellowness) of sorghum couscous reported by Galiba et al (1988).

All sorghum flours appeared white after milling. Processing of flour into couscous decreased the lightness (L) values and increased the red (a) and yellow (b) values for all the cultivars. Changes in color became obvious as soon as flour was mixed with water. These changes were accentuated during steaming and drying. Wet couscous appeared lighter in color than dry couscous. These changes in color are likely due to the presence in the flours of various phenolic compounds which have been reported to be responsible for the colors found in sorghum-based foods (Hoseney et al 1981). A sensory study conducted by our group in Niger (unpublished data) revealed that consumers accepted a wide range of sorghum couscous color, although there was a clear preference for white- and yellow-colored couscous.

A correlation analysis between flour and couscous color revealed that flour redness was the only parameter that was positively associated with couscous redness ($r = 0.83$, $P < 0.01$) and negatively with couscous yellowness ($r = -0.76$, $P < 0.05$).

Water Absorption Index and Water Solubility Index

Sidibe et al (1982) reported that couscous that absorbs a large amount of water without being sticky is highly desirable. Sorghum couscous WAI ranged from 4.9 for P721N to 6.1 for P721Q (Table V). Sorghum flours with high viscosity breakdown tended to produce couscous with high WAI.

Sorghum couscous WSI ranged from 4.0 for Mota Maradi to 6.2 for P721Q, respectively (Table V). The amount of water soluble materials (WSI) in sorghum couscous was positively correlated with

TABLE II
Chemical Composition of Decorticated Sorghum Flours

Cultivar	Ash (%, db)	Total Protein (%, db)	Albumin, Globulin, and NPN[a] (%)	Kafirins[a] (%)	Glutelin[a] (%)	Starch (%, db)	Amylose (%)	AM/AP Ratio[b]	Damaged Starch (%)
SC283-10	0.60e[c]	9.2f	6.2g	80.5bc	13.3b	89.0a	20.5c	0.299d	6.1c
NAD-1	0.81c	8.7g	9.6d	81.3a	9.1d	86.3b	18.6e	0.275e	5.6d
P721N	0.90b	9.6e	11.3c	78.5d	10.0c	78.5e	21.3bc	0.372a	5.1e
IRAT-204	0.71d	9.9d	5.9g	73.0e	21.5a	85.9b	19.7d	0.298d	7.2b
P851171	1.29a	10.3c	16.4a	70.5g	13.1b	81.9c	20.2c	0.328c	4.1f
SEPON	0.81c	10.5c	7.2f	79.6c	13.0b	82.5c	22.5a	0.375a	5.2e
P721Q	1.31a	10.2cd	14.9b	71.8f	13.5b	82.5c	20.4c	0.329c	3.2g
Mota Maradi	0.89b	11.6b	8.5e	78.2d	13.3b	82.4c	21.6ab	0.355b	5.1e

[a] Percent of total protein; NPN = nonprotein nitrogen.
[b] Amylose-to-amylopectin ratio.
[c] Means followed by the same letter in each column are not significantly different ($P < 0.05$).

TABLE III
Pasting Properties of Decorticated Sorghum Flours

Cultivar	Pasting Temperature (°C)	Peak Viscosity (BU)	Hot Paste Viscosity (BU)	Cold Paste Viscosity (BU)	Breakdown (BU)	Setback (BU)	Consistency (BU)
SC283-10	80b[a]	445b	440a	720cd	5e	275e	280e
NAD-1	80b	505a	355b	940a	150a	435bc	585a
P721N	83a	400c	360b	895a	40d	495a	535ab
IRAT-204	80b	415c	320c	805b	95c	390c	485bc
P851171	80b	430bc	295d	590e	135b	295d	160f
SEPON	83a	385d	285d	655d	100c	270e	370d
P721Q	83a	415c	285d	800b	130b	515a	385d
Mota Maradi	83a	335e	330c	780bc	5e	445b	450c

[a] Means followed by the same letter in each column are not significantly different ($P < 0.05$).

the proportion of fine flour ($r = 0.87$, $P < 0.01$) which was also found to be associated with high ash and albumin and globulin contents of flour. The soluble materials were also found to contain a significant amount of leached starch, which may have a detrimental effect on couscous stickiness.

Couscous Texture

Stickiness and mouthfeel have been reported to be the most important textural determinants of couscous quality (Sidibe et al 1982, Kaup and Walker 1986, Debbouz et al 1994). Sorghum cultivars that make very sticky couscous would be unacceptable. The stickiest couscous was obtained from IRAT-204, SC283-10, and SEPON (Table VI). Couscous stickiness positively correlated with percent damaged starch ($r = 0.89$, $P < 0.01$) and the proportion of glutelins ($r = 0.74$, $P < 0.05$) and negatively with ash content ($r = -0.76$, $P < 0.05$). There was less variation in couscous hardness than in stickiness among sorghum cultivars. The hardness of sorghum couscous was associated with apparent amylose content of flour ($r = 0.79$, $P < 0.05$) and with flour peak viscosity ($r = –0.75$, $P < 0.05$). Starch content was not associated with the hardness and stickiness of couscous, but negatively correlated with couscous chewiness ($r = –0.89$, $P < 0.01$). This is the first report correlating sorghum flour and starch characteristics to couscous textural properties. None of the physical grain and flour properties (Stenvert hardness, flour particle size) appeared to be associated with couscous texture.

Comparing Sorghum and Durum Wheat Couscous

Laboratory-prepared and commercial durum wheat couscous were lighter (L = 72.3 and 67.6, respectively), had more yellow color (b = 22.1 and 24.2, respectively), and less red color (a = 0.2 and 0.7, respectively) than sorghum couscous (Table V). These results are in agreement with those of Kaup and Walker (1986), who reported values for durum wheat couscous ranging from 51.7 to 65.6 and from 17.1 to 24.1 for lightness and yellow color, respectively. Among sorghum samples, couscous made from SEPON flour was the best in terms of its lightness and yellow color, followed by IRAT-204 and NAD-1. These three cultivars compared well to wheat couscous in terms of color.

Laboratory-prepared wheat couscous absorbed slightly less water (WAI = 4.6) and commercial wheat couscous absorbed more water (WAI = 6.4) than sorghum couscous (Table V). Debbouz and Donnelly (1996) determined WAI of homemade durum wheat couscous and reported values of 3.8–4.2. They found that couscous made from strong gluten cultivars had higher WAI than did couscous made from weak gluten cultivars. Commercial wheat couscous had a higher amount of soluble material (WSI = 7.1) than laboratory-prepared wheat and sorghum couscous.

All sorghum couscous samples were stickier and harder than durum wheat couscous (Table VI). The chewiness of durum wheat couscous was also higher than the values obtained for couscous from seven of the eight sorghum cultivars. P721N had chewiness values slightly higher than those of durum wheat couscous. This was due to the high hardness value of couscous from P721N because chewiness as a parameter is the product of hardness × springiness × cohesiveness. The relatively high chewiness of durum wheat couscous may be attributed to the functional role of gluten protein that is lacking in sorghum. In contrast to wheat gluten (prolamin and glutelin), the protein bodies that contain prolamins (kafirins) in sorghum may not have any functional role in sorghum products because they remain intact upon cooking (Rom et al 1992).

TABLE IV
Differential Scanning Calorimetry Gelatinization Temperatures and Enthalpies of Decorticated Sorghum Flours

	Gelatinization Temperatures (°C)			
Cultivar	Onset	Peak	Conclusion	Enthalpy (J/g)
SC283-10	62.7c[a]	71.1c	82.7a	5.1c
NAD-1	65.8a	72.3b	79.7c	6.1b
P721N	64.6ab	72.1b	80.8b	5.9b
IRAT-204	64.4ab	72.0b	79.6c	4.5d
P851171	63.7bc	71.3c	80.4bc	7.2a
SEPON	60.4d	68.3d	76.9d	5.7bc
P721Q	63.5bc	73.3a	82.6a	7.8a
Mota Maradi	63.3bc	71.9b	81.1b	4.4d

[a] Means followed by the same letter in each column are not significantly different (P < 0.05).

TABLE VI
Hardness, Stickiness, and Chewiness of Sorghum and Durum Wheat Couscous

Cultivar	Hardness (N)	Stickiness (Ncm)	Chewiness (N)
Sorghum			
SC283-10	16.3b[a]	2.62ab	3.0b
NAD-1	15.4b	2.06c	3.0b
P721N	18.8a	1.94cd	4.7a
IRAT-204	17.4a	3.41a	3.0b
P851171	17.9a	1.64d	3.3b
SEPON	18.5a	2.50b	3.4b
P721Q	15.6b	1.70d	3.4b
Mota Maradi	18.6a	2.03c	3.6b
Durum wheat			
Laboratory	13.4c	1.38e	4.5a
Commercial	11.7d	0.99e	4.1ab

[a] Means followed by the same letter in each column are not significantly different ($P < 0.05$).

TABLE V
Properties of Sorghum and Durum Wheat Couscous

	Particle-Size Distribution (%)			Color[a]				
Cultivar	<1.0 mm	1.0–2.0 mm	>2.0 mm	L	a	b	WAI[b]	WSI[c]
Sorghum								
SC283-10	12d[d]	68a	20ab	49.6f	6.5b	11.3i	5.6c	4.2ef
NAD-1	25c	58b	17bc	54.0d	4.0e	15.4e	5.8bc	4.0f
P721N	15d	62b	23a	48.6g	6.1c	13.1g	4.9e	4.3ef
IRAT-204	21c	67a	12d	50.4e	1.3g	16.0d	5.5c	5.1c
P851171	44a	47d	9e	48.9g	3.1f	14.4f	5.7c	5.4c
SEPON	36b	50c	14cd	56.3c	1.2g	18.7c	6.1a	4.2ef
P721Q	46a	44d	10e	47.1h	7.3a	12.5h	6.1a	6.2b
Mota Maradi	22c	58b	20ab	47.4h	4.6d	12.6h	5.2d	4.6d
Durum wheat								
Laboratory	. . .	. . .	. . .	73.2a	0.2i	22.1b	4.6e	4.9c
Commercial	. . .	. . .	. . .	67.6b	0.7h	24.2a	6.4a	7.1a

[a] L = light, a (+) = red, and b (+) = yellow.
[b] Water absorption index.
[c] Water solubility index.
[d] Means followed by the same letter in each column are not significantly different ($P < 0.05$).

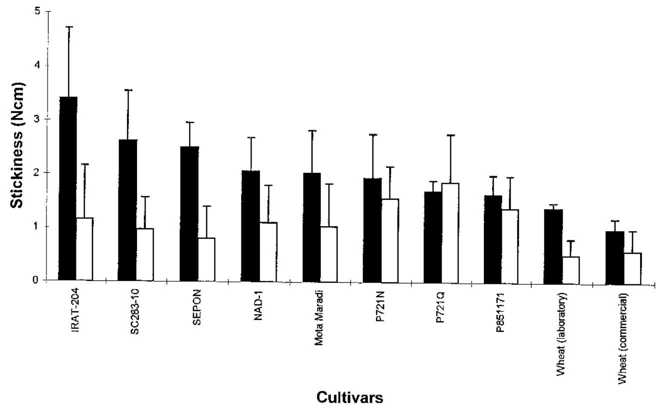

Fig. 1. Stickiness of sorghum and durum wheat couscous with (❑) and without (■) oil.

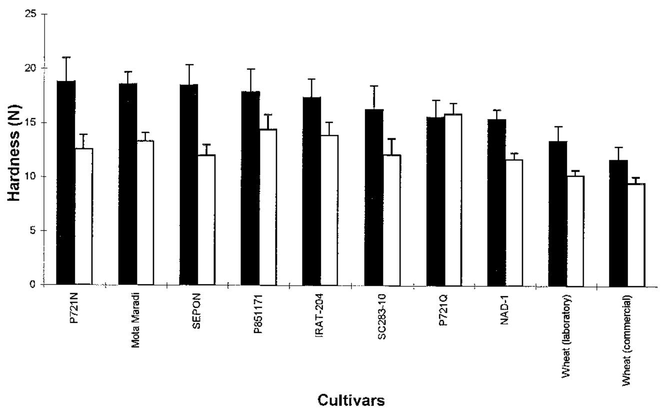

Fig. 2. Hardness of sorghum and durum wheat couscous with (❑) and without (■) oil.

Effect of Oil Addition on Couscous Texture

Addition of oil to the cooking water significantly reduced the hardness and stickiness of couscous of most of the sorghum cultivars to a level comparable to wheat couscous (Figs. 1 and 2). Cultivars IRAT-204, SC283-10, and SEPON, which produced the stickiest couscous, were more responsive to oil addition. A significant improvement in stickiness was obtained for Mota Maradi, NAD-1, and a smaller improvement for P721N and P851171. In another study (unpublished data), we found that the amount of water-soluble starch extracted from sorghum couscous positively correlated with couscous stickiness. The significant decrease in stickiness obtained after 2% oil addition to the cooking water may be due to lipid interactions with this soluble starch component. Except for P721Q couscous, addition of oil brought all the sorghum couscous to approximately the same hardness level, which was comparable to the hardness of wheat couscous. A considerable drop in chewiness was obtained for sorghum (except P721Q) and durum wheat couscous after oil addition (Fig. 3).

CONCLUSIONS

This study was conducted to determine flour properties that affect sorghum couscous yield, color, and texture. It was found that sorghum cultivars that have soft endosperm texture and produced a high proportion of fine flour also contained more bran (as indicated by ash content) and yielded high amounts of undesirable fine couscous particles. Grain characteristics for production of good quality flour for couscous preparation include hardness, ease of pericarp removal during decortication and production of high proportion of coarse flour fraction. Couscous made from flours with relatively low content of red pigment had the best color. Flours with low

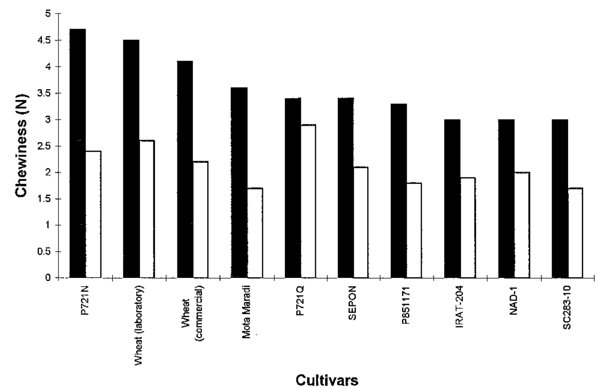

Fig. 3. Chewiness of sorghum and durum wheat couscous with (❑) and without (■) oil.

amylograph peak viscosity and low gelatinization enthalpy tended to produce couscous with hard texture. Flours with higher proportion of damaged starch produced stickier couscous. Thus, ash, flour particle-size distribution, and damaged starch content are the most important physicochemical flour parameters measured in this study that are associated with sorghum couscous quality.

In West Africa, it is desirable to find sorghum varieties or processes that make high quality couscous for commercialization in urban markets. In this way, sorghum couscous will be able to compete with imported wheat couscous. This study shows that sorghum cultivars that produce flours with high proportion of coarse particles (>125 µm) and low ash content have the highest couscous yield, and those with relatively low damaged starch content produced the best textured couscous. All sorghum couscous samples, however, were stickier and harder than durum wheat couscous. Oil addition during cooking significantly improved the texture of sorghum couscous to a level comparable to durum wheat couscous. These data suggest that addition of oil during couscous manufacture can be used as a means for controlling hardness and stickiness in couscous.

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