Malting Characteristics of Sorghum Cultivars

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ABSTRACT

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Malting properties were investigated for 16 sorghums using a germinator method and for six sorghums using a jar method. Density of caryopses decreased for all sorghums after malting. Dry matter losses ranged from 8 to 19%. α-Amylase activity determined by colorimetric assay ranged from 25 to 183 U/g, with two cultivars having activity levels similar to that of a commercial barley malt. Reduction in pasting viscosity was significantly correlated with α-amylase activity. Sorghum diastatic power (SDU) was positively correlated to α-amylase activity in cultivars with SDU values >30. β-Amylase activity was low, ranging from 11 to 41 U/g. The jar malting method yielded malts with lower dry matter losses and low levels of α-amylase and β-amylase activity, except for one cultivar. To obtain the highest levels of enzyme activity with the lowest dry matter losses, malting conditions need to be controlled and optimized.

Malts are cereals that have been steeped, germinated, and kilned under controlled conditions. Barley is traditionally the cereal chosen for malting. However, barley cultivation in tropical areas has not been successful. Thus, the production of beer (opaque and lager) and malted foods requires the importation of barley malt from temperate regions or the utilization of tropical cereals for germination and malting. Malting properties of tropical cereals have been investigated (Novellie 1962, Skinner 1976, Taylor and Boyd 1986, Aisien 1988, Aniche and Palmer 1990, Illori et al 1991, Dufour and Melotte 1992). Sorghum has been malted for centuries and is used for the production of baby food and traditional alcoholic and nonalcoholic beverages. Both α- and β-amylases are needed to hydrolyze starch and produce fermentable sugars in these processes. However, improvements and standardization of malting procedures and of malt evaluation techniques need to be made. Sorghum is commercially processed by pneumatic and floor malting methods in southern Africa. Malting conditions (moisture, temperature, time) are better controlled during pneumatic malting; the malt obtained is more uniform and better quality than that obtained from floor malting.

The objectives of this study were: 1) to determine malting properties of diverse sorghum cultivars; 2) to compare enzymatic and viscometric methods of malt evaluation; and 3) to compare two laboratory malting procedures.

MATERIALS AND METHODS

Samples

Sorghum cultivars (16) were grown at the Texas Agricultural Experiment Station in Lubbock, TX, in 1992. Samples were cleaned (DT4-1, Kice Industries, Wichita, KS). Uniform grains were collected using Tyler sieves (no. 6 [3.35 mm] or no. 7 [2.8 mm]) to remove small and broken kernels. Samples were stored at –10°C. Barley malt flour (Malt Products Corp., Maywood, NJ) was used as a reference.

Analytical Methods

Kernel characteristics (pericarp color, pigmented testa, endosperm texture, and endosperm color) were evaluated (Rooney and Miller 1982). Density (g/cm^3) was measured using a gas comparison pycnometer (MUP-IS/N232, QuantaChrome Corp., Syosset, NY). Thousand-kernel weight was determined. Test weight was determined using a Winchester bushel meter. Hardness was the percent weight remaining after milling a 20-g sample for 4 min using a tangential abrasive milling device (Reichert et al 1982). Moisture (oven dry weight) and fat (petroleum ether extraction) contents were determined in triplicate (AOAC 1980). Protein was determined in duplicate using Kjeldahl digestion. Ammonia was quantified using an autoanalyzer (Technicon 1976). Starch was determined in duplicate using the glucose hexokinase method (Technicon 1978). Malted grains were ground (1-mm mesh screen, 3010-030 cyclone mill, Udy Corp., Fort Collins, CO) before enzyme analysis.

Malting Procedures

Germinator Malting. Clean grains (100 g, triplicate samples) were placed in perforated nylon bags and steeped for 20 hr in aerated, running tap water at 28–30°C inside a container (Morall et al 1986, Taylor and Dewar 1992). After steeping, the grains were immersed in 2% sodium hypochlorite solution for 10 min and then rinsed five times with excess water. The grains were germinated at 28°C, 95% rh, for five days in a germinator equipped with a humidifier. The germinated grains were dried in a forced-air oven at 50°C for 24 hr. The dried malt was cleaned and the roots and shoots were removed by hand using a corrugated, rubber surface.

Jar Malting. Clean grains (300 g, duplicate samples) were placed in a 2-L jar, to which 0.1% formaldehyde (600 ml) was added (Palmer et al 1989, Taylor and Dewar 1992). The mouth of the jar was covered by a muslin cloth held by a rubber band throughout malting. The grains were steeped for 6 hr at 28–30°C. The water was drained, and the grains were steeped with a fresh solution of formaldehyde for 18 hr, drained, and allowed a 2-hr resting period in air. The jar was shaken gently to mix the grains and laid on its side to allow the grains to spread uniformly. Germination was allowed to proceed at 28°C for five days with water (10 ml) sprayed on the grains each morning and evening. The germinated grains were transferred to a perforated nylon bag, dried, cleaned, and separated from roots and shoots as described above.

Malt Characterization Methods

Germination activity was determined using triplicate samples (50 seeds each) in open petri dishes lined with Whatman no. 4 filter paper. Water (4 ml) was added, and the dishes were placed in a germinator at 28°C, 95% rh. Seeds that developed roots and shoots were counted after 72 hr and the percentage was recorded (Essery et al 1955).

Dry matter losses during malting were divided into losses due

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TABLE I
Kernel Characteristics, Sieve Size, Germination Energy, and Chemical Composition of 16 Sorghum Cultivars[a]

Cultivar	Grain Appearance	Pericarp Color	Pericarp Thickness[b]	Endosperm Texture[c]	Pigmented Testa	Sieve Size[d]	Germination Energy (%)	Protein[e] (%)	Starch[e] (%)
BTx378	Red	Red	2.5	2.5	No	6	81	13.2	71.8
SA3067	White	White	3.5	3.0	No	7	99	13.2	71.9
BTx2752	Bronze	Red	2.5	2.5	No	6	97	13.9	72.9
Dobbs	Off-white	White	3.0	3.0	Yes	7	98	14.3	70.5
IS9530	Red	Red	2.5	3.0	No	7	45	12.7	70.6
R9025	Red	Red	3.0	3.5	No	6	96	12.0	73.5
Red Feterita	Red	Red	3.5	3.5	Yes	6	97	13.6	70.7
Pioneer 8311	Bronze	Red	2.0	3.0	No	7	85	12.5	73.1
SC630-11E	Red	Red	2.5	3.5	No	6	43	14.6	72.1
Segaolane	White	White	2.0	2.5	No	7	94	12.2	71.8
Barnard Red	Red	Red	2.0	3.0	No	6	54	13.9	72.5
Black Sorghum	Black	Red	3.5	3.0	No	6	94	13.0	67.4
Framida	Brown	Red	3.0	4.0	Yes	6	84	12.2	70.6
SC103-12E	Brown	Red	3.0	4.0	Yes	7	99	11.9	68.1
RTx435	Yellow	White	2.0	2.0	No	6	93	12.1	70.8
Black Tx430	Black	Red	3.5	3.0	No	6	83	14.5	68.5

[a] Cultivars listed in order of increasing α-amylase activity after malting.
[b] Subjectively rated on a scale of 1–5, where 1 = thin and 5 = thick.
[c] Subjectively rated on a scale of 1–5, where 1 = corneous and 5 = floury. All had a normal distribution of amylose to amylopectin.
[d] Tyler sieves no. 6 (3.35 mm) or no. 7 (2.8 mm).
[e] Dry weight basis. Protein = (N × 6.25). Least significant difference = 1.5 (germination), 0.15 (protein), and 0.35 (starch) ($P < 0.05$).

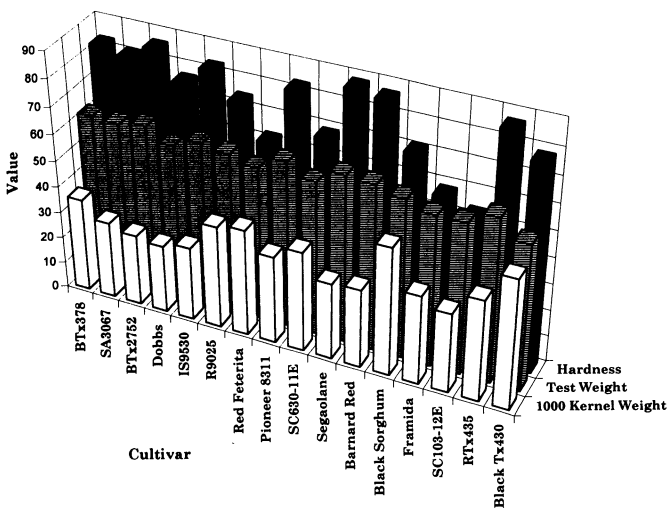

Fig. 1. Kernel weight (g/1,000-kernel weight), test weight (lb/bu), and hardness (% remaining). Sorghum cultivars are listed in order of increasing α-amylase activity after malting (left to right).

to respiration and losses due to roots and shoots removal (Novellie 1962).

Density of malted grain (60–70 g) was determined using a gas comparison pycnometer. Density readings of unmalted grain were stable after 15 sec. However, density readings of malted grain were not stable at 15 sec. Hence, a longer time (5–20 min) was required for stable readings of malted grain.

α-Amylase in malt was determined using a commercially available assay (Megazyme Pty. Ltd., Parramatta, NSW, Australia). Malt flour was extracted for 1 hr instead of 15 min (J. P. Dufour, *personal communication,* 1993). The malt extract was obtained by mixing 0.10 g (dwb) of sorghum malt with 2 ml of distilled water containing 200 ppm calcium chloride for 15 min at 23°C and shaking every 3 min. The mixture was filtered (Whatman no. 1 filter paper) and 1 ml of the filtrate was evaluated using this commercial assay.

β-Amylase activity in malt was determined by a procedure utilizing a commercially available colorimetric substrate. Sorghum malt extracts were obtained by a procedure similar to that described for α-amylase, except that 0.05*M* sodium phosphate buffer (pH 6) was used instead of water, and the extraction time was 30 min. The substrate (*p*-nitrophenol oligosaccharides) was hydrolyzed by β-amylase but was unaffected by α-amylase (Mathewson and Seabourne 1983).

α-Amylase was also assayed by measuring the decrease in viscosity using a modified Rapid Visco Analyzer (RVA-3C, Newport Scientific, Sidney, Australia) (Islas-Rubio 1993). Malt flour (0.5 g) was extracted for 1 hr with water containing 200 ppm calcium chloride. The filtered (Whatman no. 1 filter paper) extract (1 ml) was mixed with corn starch (3 g; 9.6% solids) (Argo, Best Foods, Englewood Cliffs, NJ) and distilled water (24 ml). The slurry was placed in the RVA stage, and the viscosity was monitored for 3 min at 95°C. The decrease in final viscosity of corn starch, with and without malt extract, was recorded as the reduction in paste viscosity.

Diastatic power (DP) of malt was determined using a modified peptone extraction method (Novellie 1959). Smaller amounts of malt flour (5 g instead of 25 g) and lower volume of peptone solution (100 ml instead of 500 ml) were used. Results were expressed as sorghum diastatic units (SDU).

Statistical Analysis

Analysis of variance for individual variables was performed among cultivars and within the same cultivar for each malting method. Means were separated using the least squares difference (SAS 1990). Pearson correlations were used to relate malt quality parameters and physicochemical properties of the grain. The level of significance was $P < 0.05$ for statistical methods, except as noted.

RESULTS AND DISCUSSION

The 16 sorghums had diverse kernel characteristics that represent some of the genetic variability of sorghum (Rooney and Miller 1982). (Cultivars are listed in order of increasing α-amylase activity after malting in Table I and Fig. 1.) Sorghums did not have mold growth on the kernel surface. Three of the cultivars (Barnard Red, IS9530, and SC630-11E), however, had poor germination. Germination correlated with dry matter losses from roots and shoots but did not correlate with α-amylase activity (Table II).

Vitreous endosperm texture corresponded to hardness

TABLE II
Correlation Analysis Between Physicochemical Properties of Raw Grain and Malt Quality Parameters[a]

	Hardness	TWK	Test wt	Germ	Prot	Starch	Fat	DM Loss	Root Loss	Resp Loss	Dens Raw	Dens M-un	Dens M-st	α-Amyl	β-Amyl	α:β Ratio	Visc Red
TWK	–0.23																
Test wt	**0.77**	–0.47															
Germination	–0.16	0.06	–0.06														
Protein	0.14	0.54	–0.28	–0.31													
Starch	0.49	–0.45	**0.62**	–0.17	–0.58												
Fat	–0.48	–0.34	–0.12	0.09	–0.35	–0.23											
DM loss	–0.35	0.44	**–0.69**	0.40	0.33	**–0.66**	0.03										
Root loss	–0.35	0.24	–0.51	0.54	0.08	–0.59	0.11	**0.90**									
Resp loss	–0.34	0.48	**–0.73**	0.30	0.45	**–0.68**	0.01	**0.98**	**0.80**								
Dens raw	**0.89**	–0.19	**0.68**	0.16	0.14	0.27	–0.45	–0.11	–0.06	–0.14							
Dens M-uns	**0.73**	–0.32	**0.63**	–0.14	0.02	**0.64**	–0.31	–0.50	**–0.62**	–0.42	**0.62**						
Dens M-stab	**0.67**	–0.27	0.59	–0.12	0.06	0.57	–0.24	–0.46	**–0.60**	–0.36	0.56	**0.98**					
α-Amylase	–0.24	0.48	–0.49	0.11	0.47	**–0.65**	0.34	**0.70**	0.54	**0.76**	–0.17	–0.37	–0.27				
β-Amylase	0.12	–0.39	0.29	0.07	–0.12	0.02	0.00	–0.12	0.06	–0.18	0.20	0.00	–0.04	–0.26			
β:α ratio	0.32	–0.40	0.43	0.04	–0.20	0.40	–0.34	–0.50	–0.40	–0.52	0.28	0.38	0.30	**–0.75**	**0.67**		
Visc red	–0.31	0.50	–0.56	0.10	0.49	**–0.70**	0.32	**0.75**	0.57	**0.80**	–0.21	–0.40	–0.29	**0.98**	–0.24	**–0.74**	
Diastatic power	–0.22	0.20	–0.48	0.16	0.39	**–0.68**	0.25	**0.77**	**0.71**	**0.76**	–0.07	–0.46	–0.40	**0.78**	0.24	–0.36	**0.82**

[a] Pearson correlation coefficients. All values in bold are significant at $P < 0.01$ (N = 16). Hardness: amount remaining; TWK: 1,000 kernel weight of raw grain; DM loss: total dry matter loss; root loss: dry matter loss due to roots and shoots; resp loss: dry matter loss due to respiration; dens raw: density of raw grain; dens M-un: unstable density reading at 15 sec; dens M-st: stable density reading after 5–20 min; α-amyl: α-amylase activity; β-amyl: β-amylase activity; visc red: reduction in viscosity using the Rapid Visco Analyzer.

TABLE III
Dry Matter Losses, Physical Properties, and Enzymatic Activities of Malted Sorghums[a]

	Dry Matter Losses, %			Density, g/cm³			Enzyme Activity, U/g			
Cultivar[b]	Total	Root	Resp	Raw	M-un	M-st	α-Amylase	β-Amylase	Visc Red	DP
BTx378	8.9	3.4	5.5	1.346	1.269	1.277	25	37	34	26
SA3067	9.6	4.4	5.2	1.352	1.261	1.272	36	39	50	38
BTx2752	10.9	4.8	6.2	1.371	1.245	1.255	39	41	37	34
Dobbs	15.8	6.0	9.7	1.371	1.214	1.221	42	31	49	40
IS9530	8.3	3.2	5.0	1.355	1.271	1.277	43	41	46	33
R9025	10.5	4.1	5.7	1.347	1.250	1.255	43	25	46	23
Red Feterita	15.2	5.9	9.2	1.307	1.200	1.228	46	32	58	32
Pioneer 8311	9.3	3.9	5.4	1.354	1.279	1.288	50	29	38	16
SC630-11E	8.7	2.8	5.9	1.282	1.235	1.258	54	11	54	18
Segaolane	10.6	4.8	5.8	1.377	1.265	1.273	67	14	52	23
Barnard Red	12.4	5.3	7.1	1.364	1.218	1.228	92	38	72	48
Black Sorghum	14.1	5.8	8.3	1.346	1.095	1.132	123	30	84	44
Framida	14.0	5.6	8.5	1.257	1.092	1.130	127	29	82	46
SC103-12E	14.4	5.7	9.0	1.284	1.155	1.192	146	33	95	51
RTx435	14.4	4.6	9.8	1.380	1.317	1.352	178	26	110	49
Black Tx430	19.0	6.4	12.6	1.344	1.197	1.213	183	22	110	58
Mean value	12.3	4.8	7.4	1.340	1.223	1.241	81	30	64	36
LSD ($P < 0.05$)[c]	1.1	0.8	0.8	0.002	0.007	0.008	4.7	1.2	3.8	2.6

[a] Root: dry matter loss due to roots and shoots; resp: dry matter loss due to respiration; raw: density of raw grain; M-un: unstable density reading at 15 sec; M-st: stable density reading after 5–20 min; visc red: difference between the viscosity of corn starch, with and without the malt extract, measured using Rapid Visco Analyzer units (RVU); DP: diastatic power measured in sorghum diastatic units (SDU).
[b] Listed in order of increasing α-amylase activity after malting. All values are average of two replicates with duplicate or triplicate determinations per replicate.
[c] Least significant difference.

(measured by abrasive dehulling). Hardness correlated with test weight and density of raw and malted grains (Table II). Sorghums with a pigmented testa typically have softer endosperm textures, decreased density of raw and malted grains, and more dry matter loss during malting (Table I). Test weight correlated positively with starch content and densities of raw and malted grains but negatively with dry matter and respiration losses.

Protein (13.1 ± 1.09%), fat (3.7 ± 0.60%), and starch (70.9 ± 2.03%) contents of sorghums were in the expected ranges (Table I or data not presented). Starch content of raw grain correlated negatively with respiration losses, α-amylase activity, diastatic power, and reduction in viscosity (Table II).

Dry matter losses during malting varied significantly among cultivars (Table III). The highest dry matter losses were found in sorghums with the highest α-amylase activities (Table II). Only the cultivars Dobbs and Red Feterita had high dry matter losses and low α-amylase activities. Palmer et al (1989) reported malting losses of 15–20% in sorghum compared to 7% in barley. Dry matter losses were significantly correlated to respiration loss, root and shoot loss, α-amylase activity, diastatic power, and reduction in paste viscosity (Table II).

Respiration losses of malted sorghum were higher than losses due to root and shoot growth (Table III). Respiration losses accounted for an average of 61% of dry matter losses. Respiration losses are even more important when roots and shoots are not removed, as is the case with sorghum malt for opaque beer production (Novellie 1962). Respiration losses correlated negatively with test weight and starch content, and positively with α-amylase activity.

Kernel density decreased during malting (Table III). Because stable and unstable densities of malted sorghum were correlated ($r = 0.98$), only unstable density values need to be determined. Densities of raw and malted sorghums correlated positively with test weight and hardness, and negatively with dry matter losses

(Table II). Density of malted sorghum correlated with diastatic power and reduction in pasting viscosity.

α-Amylase activity was assayed by a colorimetric procedure and by the reduction in paste viscosity using the RVA (Fig. 2, Table III). Malts prepared from Black Tx430 and RTx435 had α-amylase levels of 183 and 178 U/g, respectively. A commercial barley malt had an α-amylase activity of 189 U/g. Hence, those two sorghums had levels of α-amylase similar to those of barley malt. Similar observations were reported previously by Dufour and Melotte (1992). SC103-12E, Framida, Black Sorghum, and Barnard Red cultivars also gave malts with high α-amylase. The

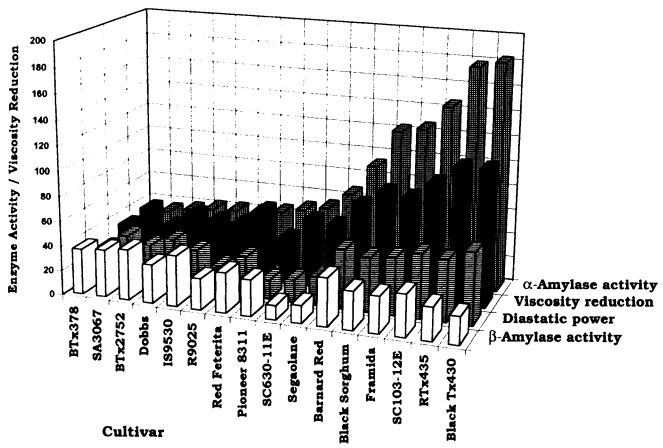

Fig. 2. β-Amylase activity (U/g), diastatic power (SDU), reduction in pasting viscosity (RVU), and α-amylase activity (U/g) of sorghum malts listed in order of increasing α-amylase activity after malting (left to right).

TABLE IV
Dry Matter Losses (%) in Sorghum Malts Produced Using Germinator (G) and Jar (J) Methods[a]

	Dry Matter		Respiration		Roots/Shoots	
Cultivar[b]	G	J	G	J	G	J
BTx378	8.9	6.8	5.5	4.1	3.4	2.7
IS9530	8.3	6.6	5.0	4.2	3.2	2.4
SC630-11E	8.7	6.4	5.9	4.2	2.8	2.2
Framida	14.0	11.3	8.5	6.4	5.5	5.1
RTx435	14.4	11.5	9.8	7.9	4.6	3.3
Black Tx430	19.0	12.4	12.6	8.7	6.3	3.7
LSD ($P < 0.05$)[c]	1.22		0.91		0.53	

[a] All values are averages of two replicates.
[b] Sorghum cultivars are listed in order of increasing α-amylase activity after malting.
[c] Least significant difference between the germinator and jar methods.

α-amylase activity correlated with increases in respiration and dry matter losses, 1,000-kernel weight, and protein content, and with decreases in test weights and starch contents (Table II).

Reduction in paste viscosity correlated with the α-amylase colorimetric assay (r = 0.98) and with DP (r = 0.82) (Table II). Rashcke et al (1993) observed that reduction in paste viscosity of sorghum malt extracts correlated with DP (r = 0.99). Booth et al (1993) measured α-amylase activity in cereal meals and flours using a similar method. Thus, viscometric methods are rapid and appear to estimate α-amylase activity and DP.

β-Amylase activity was generally low for all the cultivars after malting (Fig. 2). β-Amylase activity of barley malt was 52.3 U/g. Highest β-amylase activities (37–41 U/g) were found in BTx2752, IS9530, SA3067, Barnard Red, and BTx378. Similar observations were previously reported (Dufour and Melotte 1992). Correlations between β-amylase and all other parameters, including α-amylase activity (Table II), were not significant. Recent findings have documented that 50% of β-amylase activity is located in the acrospire (unlike α-amylase activity, which is located in the endosperm [65–70%] and embryo [25–30%]) (J. P. Dufour, *personal communication,* 1993). Therefore, removal of roots and shoots after malting probably led to a significant loss of β-amylase activity.

The ratio of β-amylase to α-amylase in sorghum malt ranged from 0.12 to 0.25 for cultivars with the highest α-amylase activities. Only Barnard Red had a higher ratio of β- to α-amylase (0.41). A β- to α-amylase ratio of 0.28 was calculated using barley malt in this study. Islas-Rubio (1993) reported a β- to α-amylase ratio of 0.65. Dufour and Melotte (1992) reported a lower β- to α-amylase ratio of 0.31 using Bendelow's procedure (1963) for α-amylase and β-amylase determinations. β-Amylase did not significantly correlate with any kernel or malting measurement (Table II).

DP ranged from 16 to 58 SDU/g of malt (Table III). Eleven of 16 malts had DP > 28 SDU/g of malt, the minimum DP specification for sorghum malt by a sorghum brewery (Taylor and Dewar 1992). Sorghums with the high DP (43 and 58 SDU/g) were Black Tx430, SC103-12E, RTx435, Barnard Red, Framida, and Black Sorghum. DP was correlated with α-amylase, reduction in paste viscosity and dry matter losses (Table II).

Morall et al (1986) observed that Barnard Red had a maximum DP of 46.6 SDU/g with five days germination at 24°C. DP ranging from 17 to 48 SDU/g were found in seven Nigerian sorghum cultivars germinated for five days (Illori 1989). Jayatissa et al (1980) also reported DP of 13 to 41 SDU/g on 17 Sri Lankan sorghum cultivars after malting; most had DP between 20 to 35 SDU/g.

Even though DP was correlated with α-amylase activity (Table II), a cubic equation (α-amylase = $151 - 8.61x + 0.166x^2$, where x = DP) had a higher correlation coefficient (r = 0.90). When val-

TABLE V
Evaluation of α- and β-Amylase Activities, Viscosity Reduction, and Diastatic Power for Sorghum Malts Obtained Using Germinator (G) and Jar (J) Methods[a]

	α-Amylase Activity (U/g)		β-Amylase Activity (U/g)		Diastatic Power (SDU)		Viscosity Reduction (SNU)	
Cultivar[b]	G	J	G	J	G	J	G	J
BTx378	16	17	37	31	26	17	34	15
IS9530	30	43	41	34	34	26	46	32
SC630	41	30	11	7	18	11	54	30
Framida	115	91	29	30	46	33	82	53
RTx435	167	51	26	14	49	11	110	30
Black Tx430	169	35	22	3	58	8	110	28
LSD ($P < 0.05$)[c]	3.7		0.9		1.9		4.4	

[a] All values are average of two replicates with duplicate or triplicate determinations per replicate.
[b] Sorghum cultivars are listed in order of increasing α-amylase activity after malting.
[c] Least significant difference.

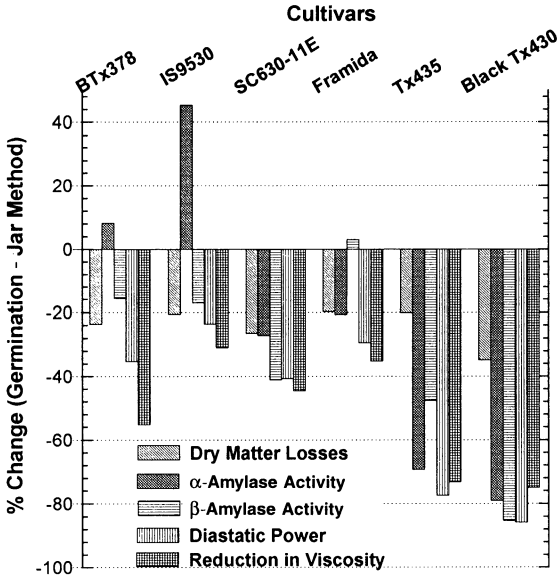

Fig. 3. Change (%) in dry matter losses, α- and β-amylase activities, diastatic power, and reduction in pasting viscosity using the jar method Reference values are from germination method.

ues for the five malts with DP < 28 SDU/g were not included, linear correlation coefficients were $r = 0.90$ for DP with α-amylase activity, $r = 0.98$ for reduction in viscosity with α-amylase activity, and $r = -0.79$ for β-amylase activity with α-amylase activity.

Comparison of Procedures

Respiration and root and shoot losses were significantly lower for malt processed by the jar method than by the germinator method (Table IV). Cultivars BTx378, IS9530, and SC630-11E had lower dry matter losses.

Cultivars with higher α-amylase activities had substantial decreases in α-amylase activity, diastatic power, and reduction in viscosity using the jar method (Table V, Fig. 3). Islas-Rubio (1993) also found decreased α-amylase activities of the malt produced using the jar method. β-Amylase activity of sorghums decreased using the jar method, except for Framida (Table V, Fig. 3). This might be the reason why Framida continues to be preferred for malting in southern Africa. Curiously, Black Tx430 had the highest DP with the germinator method and the lowest DP with the jar method.

All measures of malt characteristics were higher when processed by germinator method than when processed by the jar method, except α-amylase activity of IS9530 (Tables IV and V, Fig. 3). This supports the industrial experience that better control of humidity and temperature (germinator malting method) is required or preferred by industrial brewers, who must have higher enzyme activities. The jar method had less air movement and probably less humidity (typical floor malting conditions) compared to the pneumatic method. This apparently adversely affected the production of α- and β-amylases. Malt obtained through floor malting is commonly used for traditional home brewing where lower enzyme levels can be tolerated.

CONCLUSION

Colorimetric methods effectively quantified α- and β-amylase activities in sorghum malt. DP was correlated to the colorimetric α-amylase method and the reduction in pasting viscosity. The β-amylase activity was negatively correlated with α-amylase activity when malts with modest to high DP were included. The β-amylase activity was not significantly correlated to other methods of evaluation of malt quality. Kernels with higher test weights retained more density and solids after malting; however, their malts had lower α-amylase activities. Malts with higher dry matter losses were observed in sorghums with higher germination energies, higher α-amylase activities, and lower starch content.

Sorghum cultivars showed different malting characteristics when produced by laboratory germinator and jar methods, which are representative of the pneumatic and floor malting procedures used in southern African countries. Malt prepared using the pneumatic malt procedure had higher enzyme levels. Cultivars with higher α-amylase activities were more adversely affected by the less controlled moisture and aeration conditions in the jar method (typical of floor malting conditions). Thus, cultivar evaluations for malting must be done under conditions approximating the actual malting process.

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