Milling Value of Sorghums Compared by Adjusting Yields to a Constant Product Color

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ABSTRACT

A method of comparing milling values of sorghum by adjusting yields to standard *L* values was developed. The milling values of 'Dorado' (an excellent food-type sorghum variety), 'ATx399 x RTx430' (a commercial red sorghum hybrid) and three 'Warner 902W' (commercial white food type hybrids with different levels of weathering designated W-1, W-2, and W-3) were determined using a tangential abrasive dehulling device for various times. Color (*L, a, b*) was measured on the decorticated grain (grits) and the ground grits (flour). The yields (by weight) of flours adjusted to an *L* value of 85 were 93, 88, 86, 84, and 70% for Dorado, W-2, W-1, W-3, and red, respectively. The *b* (yellow) values were highest for red and lowest for Dorado. The grits yields were 96, 89, 84.5, 81.5, and 56.5% when adjusted to an *L* of 67 for Dorado, W-2, W-1, W-3, and red sorghums, respectively. Milling yields expressed at comparable flour or grit color clearly demonstrate that white food-type sorghums have significantly better milling yields than red sorghums. Adjusting milling yields to a standard *L* value is an accurate and easy way to compare milling properties of sorghums for yield and product color.

Sorghum is dry-milled using abrasive milling procedures to remove the pericarp, followed by reduction of the endosperm to finer particles (Rooney and Sullins 1969). The pericarp usually has a high concentration of pigments which makes many sorghum endosperm products dark and unacceptable. Size, shape, and structure of kernel and endosperm hardness are major factors that affect milling quality of sorghum (Munck 1995). Hard kernels with pearly white appearance without a pigmented testa generally have the best milling properties (Rooney and Waniska 2000).

Yield, composition, and color of endosperm fractions are key criteria for judging milling properties of sorghums (Hahn 1969). The sorghum pericarp should be easily and efficiently removed to produce clean, bright endosperm with maximum grit and flour yields.

Wet, humid weather during grain maturation causes discoloration and grain damage due to molding and weathering (Waniska and Rooney 2000). The milling quality of such grain can be adversely affected, depending on the extent of damage to the endosperm. Kernel properties associated with resistance to weathering include hardness, density, pericarp color, and thickness, and the waxy covering on the grain surface (Jambunathan et al 1992; Waniska et al 1992; Menkir et al 1996). Breeding programs are producing tan plants with bright-colored grains and improved milling properties.

Traditionally, the milling performance of sorghum has been evaluated by correlating milling time with yield of grits. This is not a very effective way of determining milling quality because grit color, which is a major quality determinant, is not taken into account. In economic terms, the grit yield that a miller can obtain from his grain at a constant color value (*L*) as a quality parameter is a better indicator of the economic worth of the sorghum. Thus, adjusting yields to a constant reference *L* value would provide easy, direct, and accurate means of judging the milling quality of sorghums. Consequently, our objectives were to compare milling properties of food-type commercial sorghums with a red commercial sorghum hybrid by adjusting yield to a constant *L* value. In addition, the effect of weathering on the milling properties of the food type sorghums was measured.

MATERIALS AND METHODS

Grain Samples

For the milling experiments, five grain samples were compared. Dorado, a white food cultivar, represented a clean, very white grain (grown in College Station, TX, in 1998). ATx399*RTx430, a commercial red hybrid with clean and bright grain (grown in College Station, TX, in 1998), and three samples of Warner-902W, a white, tan plant commercial food-type hybrid, designated as W-1 (bright, no weathering) (grown in West Texas in 1998), W-2 (slightly weathered) and W-3 (weathered) (grown in West Texas in 1999) were also used.

All samples were stored in moisture-proof bags at –18 to –22°C before analysis. The samples were equilibrated at room temperature in moisture-proof bags. Cleaning to remove all cracked grains and foreign materials was accomplished using a Carter dockage tester, followed by hand removal of any cracked, broken or otherwise damaged kernels.

Analytical Procedures

Protein and fat contents were measured using an NIR 6500 spectrophotometer following Approved Method 39-21 (AACC 2000).

Density was measured by a nitrogen gas displacement multipycnometer (model MVP-1, Quantachrome Corp., Syosset, NY). Clean representative sample (80 g) was used. The test was performed at a cell reference pressure of 15–17 psi. Volume and density of samples were calculated using the procedure described by Almeida and Rooney (1997). Test weight (Winchester bushel meter, Seedburo Equipment Co., Chicago, IL), and thousand kernel weight (TKW) were determined using the procedures described by Almeida and Rooney (1997).

Yield of decorticated grain (% weight of grit over whole grain) and milling behavior were determined by milling grain (20 g) using a tangential abrasive dehulling device (TADD) (model 4E-230, Venable Machine Works Ltd., Saskatoon, Canada). Milling was done at 1-min intervals from 1–8 min; changes in color and yield of grits were recorded. Whole grains and grits were ground using a Udy Cyclotec mill equipped with a 0.1-mm screen. The ground grits were referred to as flour.

Color values (*L, a, b*) of whole grains, grits, and flour, was measured using a chromameter (model CR-310, Minolta).

RESULTS AND DISCUSSION

Composition and Physical Attributes

Protein content varied significantly among Warner 902W samples due to different agronomic and environmental growing conditions (W-1 and 3 were grown in 1998, whereas W-2 was grown in 1997) (Table I). No significant differences were observed in fat content among the samples.

Kernel weights exhibited significant variations. Dorado, which has large kernels, had the highest TKW, followed by W-3, while W-2 had the lowest (Table I). The differences in TKW among

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W902-W samples were attributed to variable growth conditions. Test weights were high for all samples. The weathered W-3 sample had significantly lower test weight and density than W-1 and W-2. This negative effect of weathering on the physical properties of the grains has been documented (Matocha et al 1977; Waniska et al 1992).

TABLE I
Composition and Physical Attributes of Sorghum Samples

Sample	Protein[a] (%)	Fat[a] (%)	Test Wt (lb/bu)	TKW[b] (g)	Density (g/cm^3)
ATx399*RTx430	13.1	3.5	59.5	29.8	1.36
Dorado	11.2	3.5	60.8	35.1	1.36
Warner 902W-1	10.9	3.3	61.2	27.9	1.36
Warner 902W-2	9.9	3.3	61.6	26.1	1.37
Warner 902W-3	12.8	3.4	59.1	33.1	1.34
LSD (α = 0.05)	0.6	0.3	1.5	2.0	0.02

[a] Dry weight basis.
[b] Thousand kernel weight.

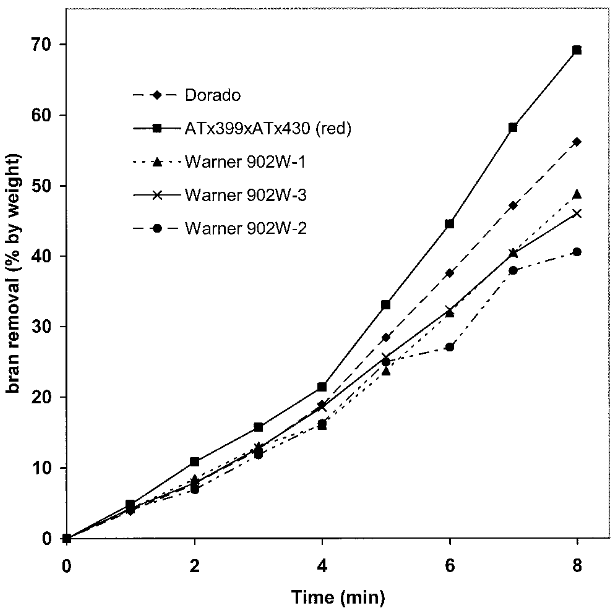

Fig. 1. Effect of decortication time on material removed from five sorghums.

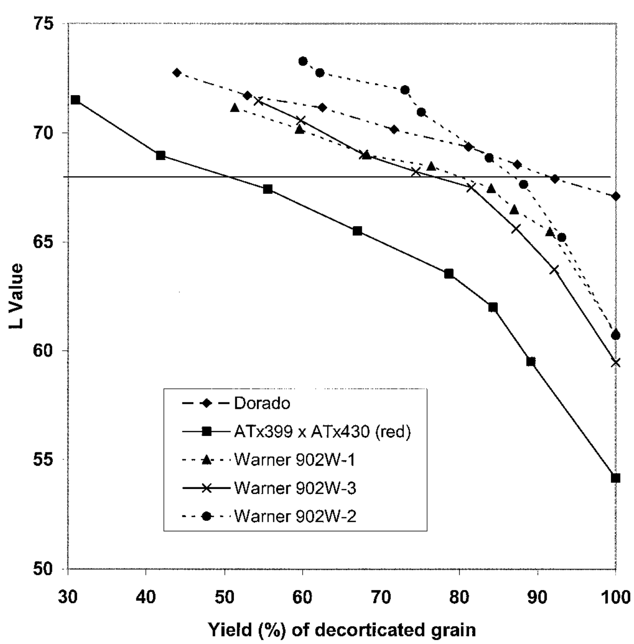

Fig. 2. Effect of decortication on *L* value of grits from five sorghums.

Effect of Decortication on Grit Yield

A nonlinear increase in percent removal of bran (by weight) with increased decortication time was observed for all samples (Fig. 1). Red sorghum had the highest removal rate, hence the lowest milling

TABLE II
Yield (%) of Milled Products Adjusted to Constant Color Values

	Decorticated Grain		Flour
Sample	Standard Method[a]	Lightness (67)[b]	Lightness (85)[c]
ATx399*RTx430	78.6a[d]	56.5a	75a
Dorado	81.1b	96.0e	93e
Warner 902W-1	84.0c	84.5c	86c
Warner 902W-2	83.8c	89.0d	88d
Warner 902W-3	81.5b	81.5b	84b
LSD	2.6	2.6	2.6

[a] Decorticated 4.0 min (Almeida-Dominguez and Rooney 1997).
[b] Yields of decorticated grain adjusted to a lightness of 67.
[c] Decorticated grain that yields a flour with a lightness value of 85.
[d] Values followed by same letter in a column not significantly different ($P < 0.05$).

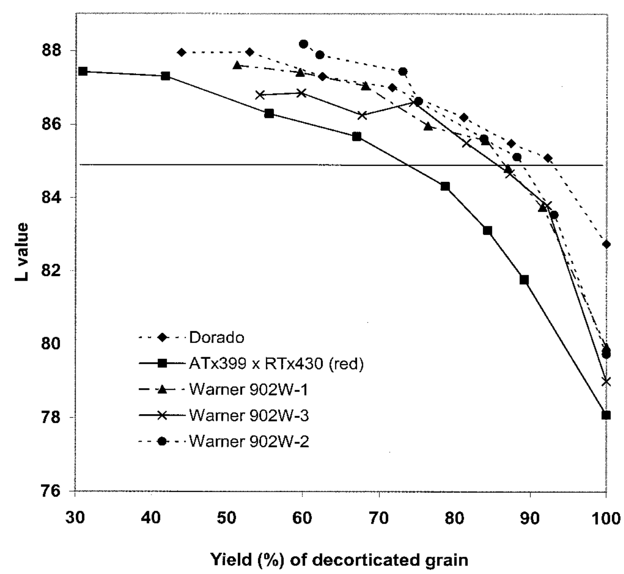

Fig. 3. Effect of decortication on *L* value of flour from five sorghums.

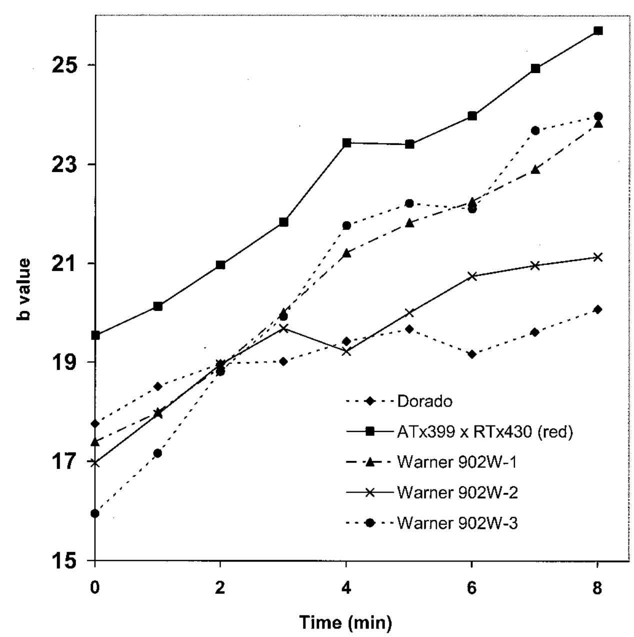

Fig. 4. Effect of decortication on *b* values of grits from five sorghums.

yield at any milling time, implying it has a softer endosperm than the other samples. The W902-W samples had a slower removal rate, and thus higher yields, than Dorado for milling times >4 min, suggesting that W902-W had the hardest endosperm. At 4 min standard milling time (Table II), W-1 (the unweathered sample) and W-2 had the highest milling yield, while the red sorghum had the lowest. The most weathered sample (based on visual observation) among the W902-W cultivars (W-3) had a significantly lower yield than W-1 and W-2 at the standard milling time ($P < 0.05$), implying that there was a significant effect of weathering on its milling quality. This was expected because weathering causes damage to the kernel endosperm, lowering its resistance to abrasion during decortication. Mold infestation of the kernel endosperm causes breakdown of the starch by fungal enzymes, weakening the endosperm structure. Milling yields of W-1 and W-2 were not significantly different at 4 min, because the effect of weathering on W-2 was localized on the grain surface.

Effect of Decortication on Flour and Grit Color

L (lightness) values decreased nonlinearly with an increase in decortication yield for all sorghums. The same trend was observed for both grits (Fig. 2) and flour (Fig. 3) samples. Flours had higher *L* values than grits because grinding dispersed the pigments among flour particles. The red sorghum had the lowest *L* value at any given decortication yield.

The reference *L* values used for comparison of the milling yields were 85 for flour (equivalent to *L* value of commercial sorghum flour), and 67 for DG which is equivalent to the *L* value of bright, white corn (Floyd et al 1995). At the reference *L* values, the red sorghum had the lowest yield and Dorado the highest (Figs. 2 and 3). Dorado was grown under experimental conditions and had very clean, bright grains. The W902-W samples had significantly different yields at the reference *L* values ($P < 0.05$), which did not correlate to the level of weathering. The most weathered sample, W-3, had the lowest yield at the flour reference *L* values among the W902-W samples, indicating a negative effect of weathering on milling quality. It also had the lowest grit yield at the comparable *L* value of 67 among the W902-W samples (Fig. 2). The slightly weathered sample, W-2, however, had higher yield than the unweathered W-1 sample. This was because the dark pigments were localized in the pericarp and, hence, had no effect on color of the milled products.

The W-2 sample had significantly reduced yellow pigmentation compared with the other W902-W samples as indicated by its low *b* (yellow) value at 8 min of milling time when almost all the pericarp was removed (Fig. 4). Seasonal variation significantly affects the β-carotene content of sorghum. At the same time, a positive correlation exists between β-carotene content and yellow endosperm color of sorghums (Hulse et al 1980). The W-2 sample was likely lower in β-carotene content. The grits were thus brighter and consequently had higher *L* values.

CONCLUSIONS

In general, distinct differences could be observed among the sorghums when milling yields were adjusted to a reference *L* value. This method is useful in evaluating and comparing abrasive milling quality of various sorghums. It clearly shows that white food-type sorghums have significantly better milling yields than red sorghum. Adjusting yields to a reference color focuses on commercial sorghum milling value by helping identify cultivars with highest yields of bright, high quality flour. The method has been successfully used to evaluate the abrasive milling properties of large numbers of sorghum lines and hybrids.

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