Factors Affecting the Color and Appearance of Sorghum Starch[1]

V. SUBRAMANIAN, R. C. HOSENEY, and P. BRAMEL-COX[2]

ABSTRACT

Cereal Chem. 71(3):275–278

Seven cultivars of grain sorghum with various seed colors were studied for the presence of light-absorbing substances in the grain and starch. A corn sample was used for comparison. Starch was isolated from both sorghum and corn. Corn starch was bright in appearance and had a yellowish tinge. Sorghum starch from the cultivars Dorado, UANL-1-V-187, and Blanco 88 was also bright in appearance and white; the seed color was pale yellow. Although Sorghum cultivar Dekalb 42Y had a pale yellow seed color, it yielded a dull-appearing starch. Kansas local, Bajio, and Tamaulipas cultivars had reddish-brown seed color and also yielded dull-appearing starch that had a reddish tint. It appears that the presence of certain alcohol-soluble components contributes to the dullness of some sorghum starches, because extraction of dull starch with methanol resulted in a brighter starch. Dehulling the grain before starch isolation improved the appearance of starch. A simple alkali test on the grain was effective in predicting the dullness of starch.

The potential of sorghum for industrial starch production is similar to that of corn. With the introduction of several high-yielding varieties and hybrids, starch production is expected to increase considerably in several parts of the world. Sorghum and corn starches have several similar characteristics. However, sorghum starch has been reported to have an off-color, whereas corn starch is white or light yellow and bright in appearance (Watson and Hirata 1955). Color of the finished sorghum starches was related to the intensity of the pigments in the pericarp and in the leaves of the sorghum plant (Watson and Hirata 1955, Freeman and Watson 1971). The discoloration of sorghum starch may be due to the presence of pigments in the pericarp that are leached into the endosperm during weathering in the field or during steeping for wet milling (Norris 1971).

Sorghum cultivars show a wide range of seed colors, from white to dark brown, depending on the presence of phenolic compounds in the pericarp (Wall and Blessin 1970). Phenolic compounds also have been found in the endosperm (Blessin et al 1963). Nip and Burns (1969 and 1971) indicated that pigments in sorghum cultivars with reddish-brown seeds differed from those in cultivars with white seeds. High-tannin, brown-colored sorghum cultivars may not be suitable for starch production. Starch adsorbs and retains condensed tannins in amounts detectable by their enzyme inhibitory effect (Davis and Hoseney 1979). The endosperm of certain sorghum cultivars may also be colored, which may contribute to the off-color of the starch. Starch made from certain white-seeded cultivars can be off-white because of a noncarotenoid pigment in the endosperm (Watson et al 1955). If the pigments could be removed, the color and appearance of the isolated sorghum starch would improve. Bleaching by alkali and sodium hypochlorite treatment improved the appearance of sorghum starch (Freeman and Watson 1971). The development of new cultivars with improved milling properties has increased the potential for using sorghum in wet milling (Rooney et al 1980).

The purpose of this study was to identify factors affecting the color and appearance (dull or bright) of sorghum starch. An additional goal was to develop a method to identify cultivars that would give bright or dull starches. In addition, methods to remove the dullness of starches were investigated.

MATERIALS AND METHODS

Grain and Starch Samples

Sorghum used in this study included Kansas local, Dekalb 42Y, and Dorado cultivars. In addition, four cultivars from Mexico (Bajio, Tamaulipas, UANL-1-V-187, and Blanco 86) were kindly

[1]Contribution 92-97-J. Kansas Agricultural Experiment Station, Manhattan. Submitted as journal article 1208 by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

[2]Visiting scientist, professor, Department of Grain Science and Industry, and assistant professor Department of Agronomy, respectively, Kansas State University, Manhattan.

supplied by Arancia S. A., De CV, Guadalajara, Mexico. A bulk corn from the local market was used for comparison. Grains were cleaned when necessary in a Carter Dockage Tester (model 73, Carter-Day Co., Minneapolis, MN). The chaff, brokens, and dust were removed with a Kice aspirator (Kice Industries, Wichita KS). Before analysis, grains were ground in a Udy cyclone mill (Udy Corporation, Fort Collins, CO) to pass through a 0.4-mm sieve. All analyses were performed at least in duplicate, unless stated otherwise. Mean values are given.

Dehulling

Sorghum grains were dehulled in a Tangential Abrasive Dehulling Device (TADD, Venables Machine Works Ltd., Saskatoon, Saskatchewan) with 12 cups and a 120-grist abrasive surface. Grains were equilibrated in an oven at 40°C overnight, followed by 3–4 hr at room temperature (24°C). Samples of grain (28 g) were placed in the cups of the TADD. Pericarp removal was visually examined. Dehulling time of 4 min was selected for sorghum. The mass of dehulled grain was calculated as a percentage of the original weight of grain.

Rapid Test for Polyphenols

Based on the observation of Blakely et al (1979), a 500-mg flour sample was placed in a test tube, and 5 ml of 0.1*N* sodium hydroxide solution was added. The contents were mixed well and allowed to stand for 30 min. The color of the mixture was observed visually.

Starch Isolation

Starch was isolated by the steeping and wet milling procedure of Watson et al (1955), with minor modifications. The starch samples were dried at 40°C to a moisture content of ~8–9%. The starch samples were used for various analyses without defatting.

Agtron Reflectance Measurements

Starch reflectance was measured in an Agtron Reflectance Meter (model M-500-A, Magnuson Engineers Inc., San Jose, CA). The instrument was calibrated by selecting the blue scale.

Treatment of Starch with Solvents

A starch sample (30 g) was twice extracted with 100 ml of methanol or chloroform for 12 hr with constant shaking; the starch was recovered by filtration. The starch was then washed with excess water in a Buchner funnel with Whatman No. 4 filter paper and dried in an oven at 40°C overnight.

UV Absorption Spectra

For determination of the absorption spectra, whole meal or starch was extracted with methanol as reported by Price et al (1978). One gram or 500 mg of meal or 5 g of starch was extracted with 20 ml of methanol for 1 hr at room temperature in a 60-ml glass tube. The contents was centrifuged at 700 × *g* for 10 min.

The UV spectra were determined by scanning methanol extract of either meal or starch, with dilution as necessary. A Varian Techtron 635 UV-VIS spectrophotometer with a 1-cm light path and scanning from 200 to 400 nm was used. Methanol served as a blank. The area under the curve for each scan was measured using a polar planimeter. Because a standard was not available, the area under the curve was used for comparing the quantity of all the absorbing material in the spectra. The concentration of UV-absorbing substances was calculated as total absorbance between 200 and 400 nm expressed as cm^2 per gram of meal or starch.

TABLE I
Characteristics of Grains and Starches Studied

Cultivars	Grain Color	Starch: Agtron Reflectance Values[a]	Starch: Visual Appearance
Sorghum			
Kansas local	Reddish brown	59.3	Dull, Off-white
Dekalb 42Y	Pale yellow	66.5	Dull, Off-white
Dorado	Yellowish white	79.3	Bright, White
Bajio local	Reddish brown	63.5	Dull, Off-white
Tamaulipas local	Reddish brown	65.3	Dull, Off-white
UANL-1-V-187	Pale yellow	80.3	Bright, White
Blanco 86	Pale yellow	81.8	Bright, White
Corn			
Bulk	Orange yellow	91.0	Bright, yellowish white

[a] Agron readings represent the mean reflectance values from two or three readings.

RESULTS AND DISCUSSION

Characteristics of Grain and Starch

Sorghum cultivars chosen for the study differed in seed color (Table I). Kansas local, Bajio, and Tamaulipas had reddish-brown colored grains. The seed color of Dekalb 42Y, UANL-1-V-187, and Blanco 86 was pale yellow; that of Dorado was yellowish-white.

Corn starch was visually bright with a light yellowish tinge. Sorghum starches from Kansas local, Dekalb 42Y, Bajio, and Tamaulipas were off-white and dull. Those from Dorado, Blanco 86, and UANL-1-V-187 were bright and white. Many polyphenols are responsible for the colors found in foods and in starch isolated from sorghum (Hoseney et al 1981). Reflectance measurement of the starch samples (Table I) showed that among the sorghums, Blanco 86, UANL-1-V-187, and Dorado had high reflectance values, ranging from 79.3 to 81.8. Corn starch had a reflectance value of 91.0. In agreement with their dull appearance, the reflectance values for starches isolated from Kansas local, Bajio, Tamaulipas, and Dekalb 42Y were low (ranging from 59.3 to 66.5).

Absorption Spectra of Meal Extracts

The visual color of the methanol extracts of sorghum meal varied from colorless to light pink or red. Extracts of Dorado, UANL-1-V-187, and Blanco 86 were colorless, whereas extracts of other cultivars were light pink or red in color. The UV spectra of methanol extracts of meals of Bajio, UANL-1-V-187, and corn showed three peaks at 319, 290, and 213 nm, respectively (Fig. 1). The absorption spectrum of methanol extracts of corn meal was similar to that of sorghum meal.

Absorption Spectra of Starch Extracts

Methanol extracts of starch also yielded three UV peaks (Fig. 2). The peaks at 290 and 319 nm were present in both sorghum

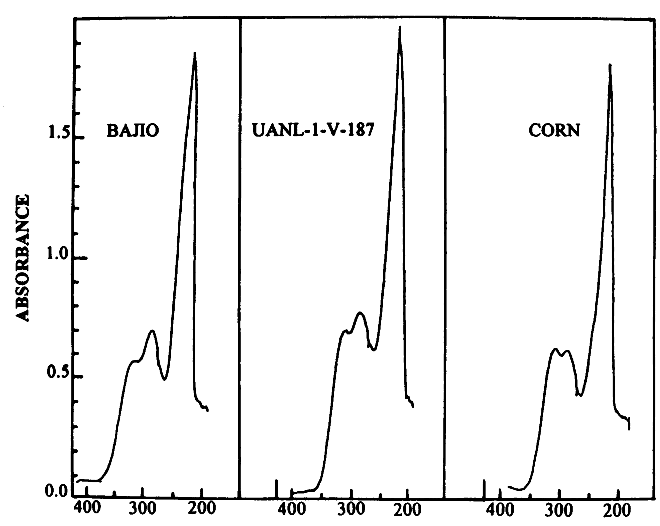

Fig. 1. UV absorption of methanol extracts of sorghum meals.

and corn starch extracts and were similar to those in the meal extracts. For sorghum starches, the peak at 213 nm was resolved into two peaks (with maxima at 213 and 235 nm) in starch extracts instead of the single peak found in extracts of meals. The starches possessing a dull appearance (Bajio, Tamaulipas, Dekalb 42Y) had larger 235 nm peaks than did extracts of starches isolated from UANL-1-V-187, Blanco 86, and Dorado, which were bright in appearance (Fig. 1).

Concentration of UV-absorbing Substances

The concentrations of UV-absorbing substances in grain and starch were compared. Concentrations of UV-absorbing substances (area under the absorption curve) of methanol extracts of meal were high in Bajio, Tamaulipas, and the Kansas local (Table II), whose grains were reddish-brown in color. Dekalb 42Y and Dorado had higher concentrations of extractable substances than did UANL-1-V-187 and Blanco 86, although all three had a pale-yellow seed color. Dekalb 42Y and Dorado had similar concentrations. Corn had a high concentration of UV light-absorbing substances, similar to that of Kansas local sorghum. Of course, having the same absorbance does not necessarily mean the components are the same.

Based on appearance, the sorghum starches were ranked in decreasing order of brightness: Blanco 86, UÁNL-1-V-187, Dorado, Dekalb 42Y, Tamaulipas, Bajio, and Kansas local. The ranking corresponds well with reflectance values (Table I).

Studies on Dull Appearance of Starch

When Blanco 86 (bright starch), Bajio, and Dekalb 42Y (dull starches) were extracted with methanol for 12 hr, all the starches became visually bright. The increase in brightness upon removal of the methanol-extractable material suggests that the extractable material is related to dullness. We did not attempt to identify the material. However, extraction of the starch with chloroform did not brighten the starch.

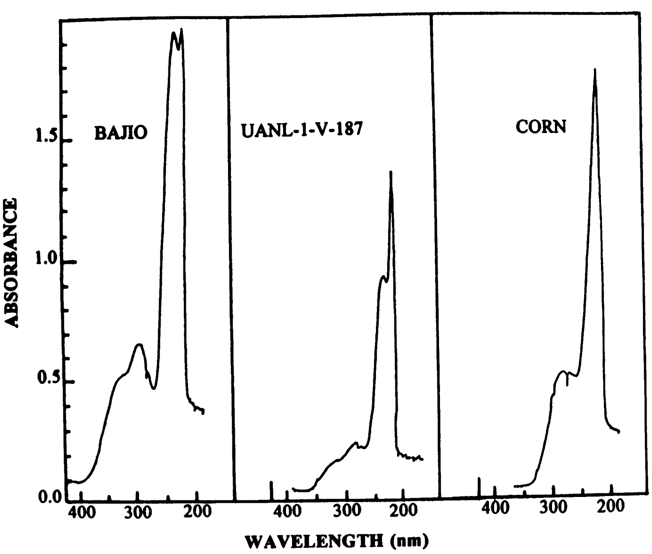

Fig. 2. UV absorption of methanol extracts of sorghum starches.

TABLE II
Concentration of UV-Absorbing Substances in Grain and Starch[a]

Cultivar	Methanol Extract Meal	Methanol Extract Starch
Sorghum		
Kansas local	130.0	7.7
Dekalb 42Y	98.7	5.1
Dorado	98.8	4.4
Bajio local	188.4	4.1
Tamaulipas local	150.4	5.8
UANL-1-V-187	73.0	3.0
Blanco 86	65.2	2.2
Corn		
Bulk	122.8	7.6
Standard error	±14.45	±0.70

[a] Absorbance (per gram) was expressed as area in cm^2 occupied by scan taken from 200 to 400 nm; values are means from two independent determinations.

Treatment of the Meal with Base

Treatment of sorghum meals with 0.1*N* sodium hydroxide solution gave variation in color of the meal-alkali mixture. Polyphenols have been detected by exposing sorghum endosperm to alkali (Blakely et al 1979). The meals of sorghum varieties that gave starches with poor color and dull appearance (Bajio, Kansas local, Tamaulipas, and Dekalb 42Y) gave a yellowish-brown color with sodium hydroxide solution. Sorghum meals from Dorado, UANL-1-V-187, and Blanco 86 gave a bright-yellow color with sodium hydroxide solution. This test is simple and may be useful in screening for cultivars that produce bright starch.

Color Removal in Starch by Dehulling

Dehulling removes the outer layers of the grain, which include pericarp and part of the endosperm. This process may remove the pigments present in pericarp and, thus, when the grain is wetted, leaching of those pigments into the starch can be reduced. The yield of dehulled grain was higher for UANL-1-V-187, Kansas local, and Blanco 86 than it was for the other cultivars (Table III). Mass losses as a result of dehulling varied from 15.9 to 32.6%. Reflectance measurements for starch isolated from the dehulled grain were higher than those for the whole grain (Table III). This suggests that dehulling resulted in brighter sorghum starch. The starches obtained from whole grain and dehulled grain were compared by UV-absorption of methanol extracts. The results obtained for the three reddish-brown sorghum cultivars (Kansas local, Bajio, and Tamaulipas) are given in Table IV.

TABLE III
Effects of Grain Dehulling on Reflectance of Sorghum Starch[a]

Cultivars	Kernel Loss by Dehulling, %	Agron Values[b] for Starch Whole Grain	Agron Values[b] for Starch Dehulled Grain
Kansas	19.3	60.0	78.0
Dekalb 42Y	21.6	71.0	81.0
Dorado	24.7	80.8	88.0
Bajio local	32.6	63.7	82.0
Tamaulipas	29.9	65.9	79.0
UANL-1-V-187	15.9	80.5	85.0
Blanco 86	19.5	82.5	88.0
Standard error	±2.29	±3.49	±1.54

[a] A quantity of 28 g of grains in two replicates was dehulled for 4 min in a Tangential Abrasive Dehulling Device.
[b] Values are means of two readings. Starch was isolated from dehulled grain and used for reflectance measurements.

TABLE IV
Reduction (%) in Concentration of UV-absorbing Substances in Starch after Dehulling[a]

Starch	Methanol Extract Absorbance[b]	Methanol Extract Reduction
Kansas Local		
Control	7.6	...
Dehulled grain	2.7	64.5
Bajio		
Control	7.2	...
Dehulled grain	3.3	54.2
Tamaulipas		
Control	5.8	...
Dehulled grain	3.2	44.8
Standard error	±0.88	±7.02

[a] Starch extracted from grains dehulled in a Tangential Abrasive Dehulling Device for 4 min.
[b] Absorbance (per gram) was expressed as area in cm^2 occupied by scan taken from 200 to 400 nm; values are means of two independent determinations.

Dehulling reduced the concentration of absorbing substances in the methanol extracts of all three sorghums. The results indicate that dehulling of grain improved the appearance of starch (Table III).

As a result of dehulling, the steeping time during starch manufacture can be reduced. A balance between dehulling loss and reduction of steeping time must be considered. Dehulling may be necessary for brown sorghum or sorghums that produce dull starch, even though their pericarp color is white or yellow.

CONCLUSIONS

Our study suggests that cultivars with white or pale-yellow seeds like Dorado, UANL-1-V-187, and Blanco 86, which will produce a bright-yellow color with sodium hydroxide solution, are most suitable for starch production. Adoption of such cultivars, either by introduction or improvement by breeding, may be more practical than dehulling and other treatments. However, in areas where bird problems are prevalent, red or brown sorghums normally are preferred for cultivation. They require dehulling for starch manufacture. Dullness also can be reduced by extracting the starch with methanol.

ACKNOWLEDGMENTS

We thank Arancia S. A., De CV, Guadalajara, Mexico for the financial support for this project. We thank Adam Aboubacar for technical assistance.

LITERATURE CITED

BLAKELY, M. E., ROONEY, L. W., SULLINS, R. D., and MILLER, F. R. 1979. Microscopy of the pericarp and the tests of different genotypes of sorghum. Crop Sci. 19:837.

BLESSIN, C. W., VAN ETTEN, C. H., and DIMLER, R. J. 1963. An examination of anthocyanogens in grain sorghums. Cereal Chem. 40:241.

DAVIS, A. B., and HOSENEY, R. C. 1979. Grain sorghum condensed tannins. I. Isolation, estimation and selective adsorption by starch. Cereal Chem. 56:310.

FREEMAN, J. E., and WATSON, S. A. 1971. Influence of sorghum endosperm pigments on starch quality. Cereal Sci. Today 16:378.

HOSENEY, R. C., VARRIANO-MARSTON, E., and DENDY, D. A. V. 1981. Sorghum and millets. Pages 71-144 in: Advances in Cereal Science and Technology, Vol. 4. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

NIP, W. K., and BURNS, E. E. 1969. Pigment characterization in grain sorghum. I. Red varieties. Cereal Chem. 46:490.

NIP, W. K., and BURNS, E. E. 1971. Pigment characterization in grain sorghum. II. White varieties. Cereal Chem. 48:74.

NORRIS, J. R. 1971. Chemical, physical, and histological characteristics of sorghum grain as related to wet milling properties. PhD dissertation. Texas A&M University: College Station, TX.

PRICE, M. L., VAN SCOYOC, S., and BUTLER, L. G. 1978. A critical evaluation of the vanillin reaction as an assay for tannin in sorghum grain. J. Agric. Food Chem. 26:1214.

ROONEY, L. W., KHAN, M. N., and EARP, C. F. 1980. The technology of sorghum products. Pages 513-554 in: Cereals for Food and Beverages: Recent Progress in Cereal Chemistry and Technology. G. E. Inglett and L. Munch, eds. Academic Press: New York.

WALL, J. S., and BLESSIN, C. W. 1970. Composition of sorghum plant and grain. Pages 118-166 in: Sorghum Production and Utilization. J. S. Wall and W. M. Ross, eds. Avi Publishing Co.: Westport, CT.

WATSON, S. A., and HIRATA, Y. 1955. The wet milling properties of grain sorghums. Agron. J. 47:11.

WATSON, S. A., SANDERS, E. H., WAKELY, R. D., and WILLIAMS, C. B. 1955. Peripheral cells of the endosperms of grain sorghum and corn and their influence on starch purification. Cereal Chem. 32:165.

[Received September 24, 1993. Accepted January 25, 1994.]