

NOTE

Soluble Sugars in Five Endosperm Types of Sorghum¹

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ABSTRACT

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Total soluble sugars and their composition were analyzed in five endosperm types of sorghum (*Sorghum bicolor*). Total sugar values were highest (2.47-3.41%) in the sugary and high-lysine types and intermediate

(1.79-2.03%) in the *vani* and *basmati* types. The glucose + fructose fraction predominated in the sugary and high-lysine types, whereas sucrose was the major component in the two *vani* types.

The composition of sugars in sorghum (*Sorghum bicolor* (L.) Moench) has been reviewed by Hoseney et al (1981). Total sugar content in sorghum varies according to the stage of grain development (Bhatia et al 1972, Newton et al 1983, Subramanian et al 1983). Sugary sorghums are known to contain twice the quantity

of sugars as normal sorghums (Watson and Hirata 1960, Karper and Quinby 1963). Prasada Rao and Murty (1982) summarized information on sorghums used for special purposes, e.g., *vani* and *basmati* (scented). Mature grains of sugary and *vani* types are abnormal and have deformed endosperms. Similarly, high-lysine (hl) sorghums of Ethiopia (IS 11758 and IS 11167) have defective endosperms caused by the hl gene and contain high amounts of total sugars as well (Singh and Axtell 1973, Subramanian et al 1980). In the state of Maharashtra in India, *vani* sorghums are consumed as a sweet snack called *hurda* when the grains are in the dough stage. In a study of the nutritional value of 16 *vani* types, Rambhapur *vani* (R *vani*) and Malkapur *vani* (M *vani*) were judged the best (Bapat et al 1984).

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The sugary and *vani* types of grains were reported to be controlled by single recessive genes that were concluded to be allelic and the same (Schertz and Stephens 1966). The *basmati* and the dimpled nature of the grains of the *basmati* sorghum KEP 472 are controlled independently by single recessive genes (Murty et al 1982). The objective of our study was to compare the quantity and quality of sugars in the various endosperm types. Results could be helpful in understanding the carbohydrate metabolism in these endosperms and in identifying the nature of sugars contributing to their special food value.

MATERIALS AND METHODS

Seeds of sugary, *vani*, and *basmati* types of sorghum were obtained from the Genetic Resources Unit of ICRISAT. The seed of sugary type IS 5614 is small and has a wrinkled, hard, and crystalline endosperm (Fig. 1). Seed of *basmati* type KEP 472 is dimpled or pitted on the side opposite the hilum (Murty et al 1982). Seeds of R *vani* and M *vani* also are dimpled and have soft endosperms. The high-lysine sorghums from Ethiopia are photosensitive, and to avoid problems in seed setting at ICRISAT, seeds of two photoinsensitive derivatives of IS 11758 possessing the *hl* gene were obtained from V. J. M. Rao of the All India Coordinated Sorghum Improvement Project, Hyderabad. Seeds of these derivatives, L 1 and L 2, are soft and shriveled like those of the Ethiopian parents. The seed of the normal grain sorghum SPV 350 is plump and has a corneous endosperm.

Seeds of SPV 350, KEP 472, R *vani*, M *vani*, IS 5614, L 1, and L 2 were sown in adjacent plots during the post-rainy seasons of 1982 and 1983 at ICRISAT. Grains from these plots were sampled at two stages of development: 1) 22 days after flowering and 2) physiological maturity, i.e., after black layer formation (33–39 days after flowering).

Seed samples were freeze-dried, then ground in a Udy cyclone mill provided with a 0.4-mm screen. The samples were defatted with *n*-hexane in a Soxhlet apparatus. Total nitrogen was estimated by the colorimetric method using a Technicon auto-analyzer (Singh and Jambunathan 1980), and protein was estimated by multiplying the nitrogen content by a factor of 6.25. Lysine levels were estimated by the dye binding capacity method (Udy 1971).

Total Soluble Sugars

Soluble sugars were extracted with 80% ethanol and estimated colorimetrically by the phenol-sulfuric acid method (Dubois et al 1956). The mean coefficient of variation for estimating total soluble sugars by this procedure was 2.8%. Total soluble sugars were estimated from grain samples collected during both years.

Separation of Sugars by Thin-Layer Chromatography

Grain samples harvested at physiological maturity in 1982 were used for a detailed study of the composition of soluble sugars.

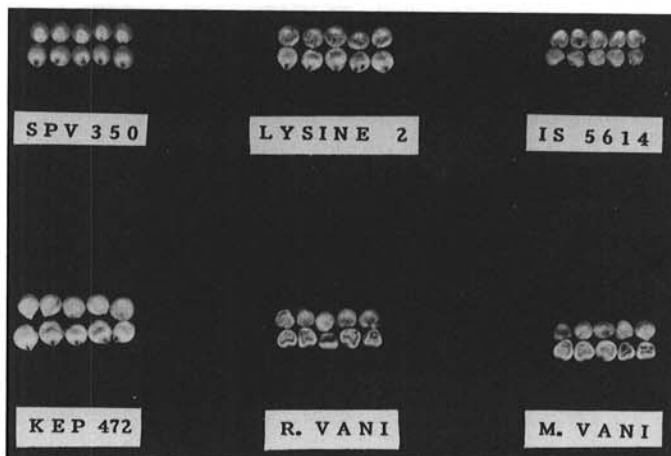


Fig. 1. Endosperm variants in sorghum (scale 1:1).

Thin-layer chromatography (TLC) was done on silica gel G plates 500 μ m thick (De Stefanis and Ponte 1968), using a solvent of chloroform, acetic acid, and water (6:7:1 v/v). The separated sugars were detected by spraying with an aniline-diphenylamine solution prepared by mixing equal proportions of 1% aniline and 1% diphenylamine in acetone, then adding two proportions of 85% phosphoric acid. Equal concentrations of sugars were applied for each sample. The sugars in the extracts were determined according to the procedure described earlier. The sugars separated by TLC were scanned in a densitometer, and the area of the peaks and their concentrations were estimated by comparison with data obtained for the respective standard sugars under similar conditions. Glucose and fructose did not separate completely and therefore were analyzed together. The mean coefficient of variation for the separation of different sugars by this method ranged between 3.4 and 8.2%.

RESULTS AND DISCUSSION

The derivatives from the high-lysine sorghum (L 1 and L 2) had the highest protein and lysine values, and the normal (SPV 350) and

TABLE I
Chemical Composition of Five Endosperm Types of Sorghum at Two Stages of Seed Development^a

Type	Protein (%)	Lysine (%)	Total Sugars (%)	
			22 Days After Flowering	Physiological Maturity
Normal				
SPV 350	10.7	1.87	2.56	1.50
<i>Basmati</i>				
KEP 472	12.8	1.95	3.01	1.80
<i>Vani</i>				
Rambhapur <i>vani</i>	12.5	2.39	4.47	1.79
Malkapur <i>vani</i>	14.3	2.25	4.43	2.03
Sugary				
IS 5614	12.7	2.42	6.29	2.47
High-lysine				
L 1	14.2	2.73	8.18	2.85
L 2	13.8	2.97	7.42	3.41
Mean	13.0	2.37	5.19	2.26
SE \pm	0.45	0.11	0.68	0.19

^aAll values averaged over two independent observations each in two years.

TABLE II
Composition of Soluble Sugars (g/100 g) in Grain at Physiological Maturity Among Five Endosperm Types of Sorghum^a

Type	Total (%)	Stachyose	Raffinose	Sucrose	Glucose + Fructose
Normal					
SPV 350	1.34	0.064 (4.8)	0.153 (11.4)	0.606 (45.2)	0.518 (38.6)
<i>Basmati</i>					
KEP 472	1.73	0.054 (3.1)	0.136 (7.9)	0.825 (47.7)	0.715 (41.3)
<i>Vani</i>					
Rambhapur <i>vani</i>	1.98	0.061 (3.1)	0.224 (11.3)	0.986 (49.8)	0.709 (35.8)
Malkapur <i>vani</i>	2.03	0.092 (4.5)	0.200 (9.8)	1.069 (52.7)	0.669 (33.0)
Sugary					
IS 5614	2.21	0.062 (2.8)	0.394 (17.8)	0.809 (36.6)	0.946 (42.8)
High-lysine					
L 1	2.48	0.123 (5.0)	0.421 (17.0)	0.897 (36.2)	1.040 (41.9)
L 2	2.67	0.098 (3.7)	0.359 (13.3)	0.992 (37.1)	1.222 (45.8)
Mean	2.06	0.079	0.270	0.883	0.831
SE \pm	0.17	0.010	0.045	0.058	0.093

^aAll values averaged over two independent observations. Values in parentheses are percentages of respective soluble sugars.

basmati (KEP 472) types had the lowest lysine values (Table I). The total sugar content of green seeds (22 days after flowering) was double that of physiologically mature seeds. The green seeds of the sugary sorghum (IS 5614) and of L 1 and L 2 had very high total sugar values, whereas values for the two *vani* types and the *basmati* type were in the intermediate range and the value for the normal type was low. Total sugar values in physiologically mature seeds ranged from 1.50 to 3.41%; values were lowest in the normal sorghum, intermediate in the *vani* and *basmati* types, and highest in the sugary and high-lysine types.

Sucrose and glucose + fructose were the major components of the soluble sugars in physiologically mature seeds (33–39 days after flowering) (Table II). The glucose + fructose values ranged from 33.0 to 45.8% and the sucrose values, from 36.2 to 52.7%. The range of stachyose values among the seven sorghums was limited. Raffinose values were higher in the sugary and high-lysine types (13.3–17.8) than in the normal, *basmati*, and *vani* types (7.9–11.4). The *basmati* and *vani* types were characterized by relatively high sucrose and low glucose + fructose fractions and the sugary and high-lysine types, by relatively high glucose + fructose and low sucrose fractions. In the normal type, sucrose values were intermediate and glucose + fructose values were low. The differences in sugar composition of the *basmati* and *vani* types on the one hand and the sugary and high-lysine types on the other possibly reflect a dissimilar genetic basis.

The total sugar content observed in the seven endosperm variants agrees with the reports of Watson and Hirata (1960) and Bhatia et al (1972). Neucere and Sumrell (1980), however, obtained much higher values for total sugars among seven varieties of sorghum. The glucose + fructose values reported by Subramanian et al (1980) were much lower, and those reported by Neucere and Sumrell (1980) much higher, than those in our study. These discrepancies could probably be explained by variations in the analytical methods used and by the nature of the material studied. Newton et al (1983) found that glucose and fructose concentrations in a normal sorghum declined rapidly 19–45 days after flowering. Apparently, even small differences in sampling periods and growing environments can affect sugar composition analyses.

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