Characterization of Starch from Pearl Millets[1]

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ABSTRACT

Starch isolated from five random-mating populations of pearl millet varied in cold water-binding capacity (83.6–99.5%) and initial (59–63°C) and end point (68–70°C) gelatinization temperatures. Swelling power at 95°C varied between 14.1 and 16.4; starches with low swelling powers also were less soluble during heating. More variations among starch amylograms were observed during the cooling than the heating cycle, suggesting that some starches tend to retrograde less than others. Small variations in amylose contents (20–22%) among starches indicated that other physicochemical factors, such as molecular dimensions, may be more important than amylose content in determining the characteristics of pearl millet starches.

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Various species of millet are grown in Africa and India. Pearl millet (*Pennisetum americanum* (L.) Leeke), known in India as bajra and in Africa as bulrush, is drought resistant and extensively grown as a food grain.

Although the major component of pearl millet is starch, properties of the starch have not been extensively studied, especially its variability among random mating populations. This paper characterizes the physicochemical properties of starches isolated from various populations of pearl millet.

MATERIALS AND METHODS

Materials

Four different random-mating bulk populations of pearl millet were used in this study: HMP550 (Tift 23 DB_1/*2PI185642); HMP1700 (PI263540/Tift 23 DB_1/2/Tift 239 DB_2/2*Serere 3A); RMPI(S)CI (parentage from Serere 3A, Serere 17, and Tift 239 DB_2); and Serere 3A, developed by Serere Experiment Station, Uganda, Africa. The HMP550 and 1700 were grown at Hays Branch Experiment Station, Hays, KS, in 1977; Serere 3A was grown in 1975 at Hays. Two RMPI(S)CI samples grown in Manhattan, KS, in 1976 (RMP'76) and 1978 (RMP'78) were analyzed. The method of Purdy et al (1968) was used to describe pedigrees of the millet samples.

Starch Isolation

Millet grain was soaked at 4°C for 24 hr in distilled water containing 0.01% sodum azide to inhibit microbial growth. After soaking, the grain was washed several times with distilled water, wet milled in a Waring Blendor for 3 min, and screened through a 116-μm bolting cloth. The process of wet milling was repeated until no more starch could be separated. The starch suspension was centrifuged at 1,000 × g for 20 min, and the upper layer (protein) of the residue was removed with a spatula and discarded. The starch (lower layer) was suspended in water, centrifuged, and the tailings scraped off with a spatula. The last step was repeated until a white prime starch (free of tailings) was obtained; then the starch was air dried.

Characterization of Starch

Protein, fat, ash, and moisture contents of the starches were determined by AOAC methods (1975). Cold water binding capacity was determined by the method of Medcalf and Gilles (1965) and starch damage, by the AACC method (1972). Starch gelatinization temperature ranges were measured with a polarizing microscope and a Kofler hot stage (Schoch and Maywald 1956). Initial, midpoint, and end point values were reported.

Intrinsic viscosities of starches were determined at 35°C according to Leach (1963) with a Cannon-Fenske viscometer, capillary size 50.

Starch swelling and solubility patterns were determined by the methods of Leach et al (1959). Pasting curves of the isolated starches were determined with an amylograph. The starch (9%, 14% mb) was suspended in buffer (AACC 1972), heated from 30–95°C, held for 1 hr at 95°C, cooled to 50°C, and held at 50°C for 1 hr.

Starch was fractionated by the method of Banks and Greenwood (1967). Amylose contents were determined by the method of McCready and Hassid (1943), and iodine affinities were determined according to Schoch (1964).

X-ray diffraction patterns of starch were determined with an x-ray diffractometer (Philips). The sample was packed in an aluminum frame and equilibrated to 96% rh. X-rays were CuKα radiation; samples were run at 35 KV, 18 mA.

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RESULTS AND DISCUSSION

Proximate analyses of the isolated millet starches are shown in Table I. Except for RMP'76 and Serere 3A, protein contents of millet starches were higher than most laboratory wet-milled cereal starches and agree with values reported by Freeman and Bocan (1973). Fat contents of pearl millet starches were high and probably reflect pearl millet's high lipid content (Lai and Varriano-Marston 1980).

Cold water binding capacity of starches varied from 83.6% for HMP550 to 99.5% for HMP1700 (Table II). Variations in water absorption may be caused by inherent differences in the proportion of crystalline and amorphous areas in the granules. Starches containing a higher proportion of amorphous material would presumably imbibe more water. X-ray diffraction patterns of millet starches (Fig. 1) showed the A-type x-ray pattern and indicated that the HMP550 starch was more crystalline than the HMP1700 sample, which may explain the higher cold water imbibition by the latter starch.

Starch crystallinity may be affected by mechanical and/or amylolytic activity. Starch damage determinations showed that all isolated millet starches had immeasurably low damage. Physicochemical differences among our millet starches were therefore caused by inherent molecular dissimilarities.

Starch gelatinization temperature ranges provide information on starch granule structure. Initiation temperatures varied from 59 to 63°C; end point temperatures, from 68 to 70°C (Table II). Genetic or environmental factors may be responsible for the differences among cultivars. Freeman et al (1968) have shown that environmental temperature during grain maturation can cause differences in starch gelatinization temperatures among cultivars.

Because swelling and solubility patterns provide information on the associative forces within the granule (Leach et al 1959), those

TABLE I
Proximate Analyses of Pearl Millet Starches

Starch	Protein[a] (%)	Fat (%)	Ash (%)	Moisture (%)
HMP1700	0.77	0.09	0.12	10.8
Serere 3A	0.44	0.11	0.12	13.7
HMP550	0.66	0.13	0.13	14.1
RMP'78	0.66	0.11	0.12	14.0
RMP'76	0.55	0.19	0.10	13.0

[a]Nitrogen × 6.25.

TABLE II
Water Binding Capacity and Gelatinization Temperature Ranges of Pearl Millet Starches[a]

Starch	Water Binding Capacity[b] (%)	Gelatinization Temperature (°C)		
		Initial	Midpoint	End Point
HMP1700	99.5 a	59	65	68.5
Serere 3A	85.0 b	61	65.5	68
HMP550	83.6 b	60.5	65	68
RMP'78	85.0 b	63	67.5	69
RMP'76	84.5 b	62	67.5	70

[a]Values represent the mean of four determinations.
[b]Values followed by different letters differ significantly ($P < 0.01$).

TABLE III
Swelling Power of Starches Isolated from Pearl Millets[a]

Temperature (°C)	Random Mating Populations				
	HMP550	Serere 3A	HMP1700	RMP'76	RMP'78
60	2.1 ab	2.3 a	2.3 a	2.0 b	2.0 b
65	4.1 a	3.6 a	3.7 a	2.5 b	2.2 b
70	7.3 a	6.6 ab	7.3 a	5.8 bc	5.2 c
75	9.5 a	8.6 bc	9.3 ab	9.6 a	8.3 c
80	10.4 a	9.5 a	10.2 a	10.8 a	9.9 a
85	11.1 a	10.5 a	10.9 a	12.5 a	11.5 a
90	13.5 a	12.2 a	12.4 a	13.3 a	14.1 a
95	14.3 a	14.3 a	14.1 a	15.4 a	16.4 a

[a]Values represent the mean of three determinations. Within each temperature, values followed by different letters differ significantly ($P < 0.05$).

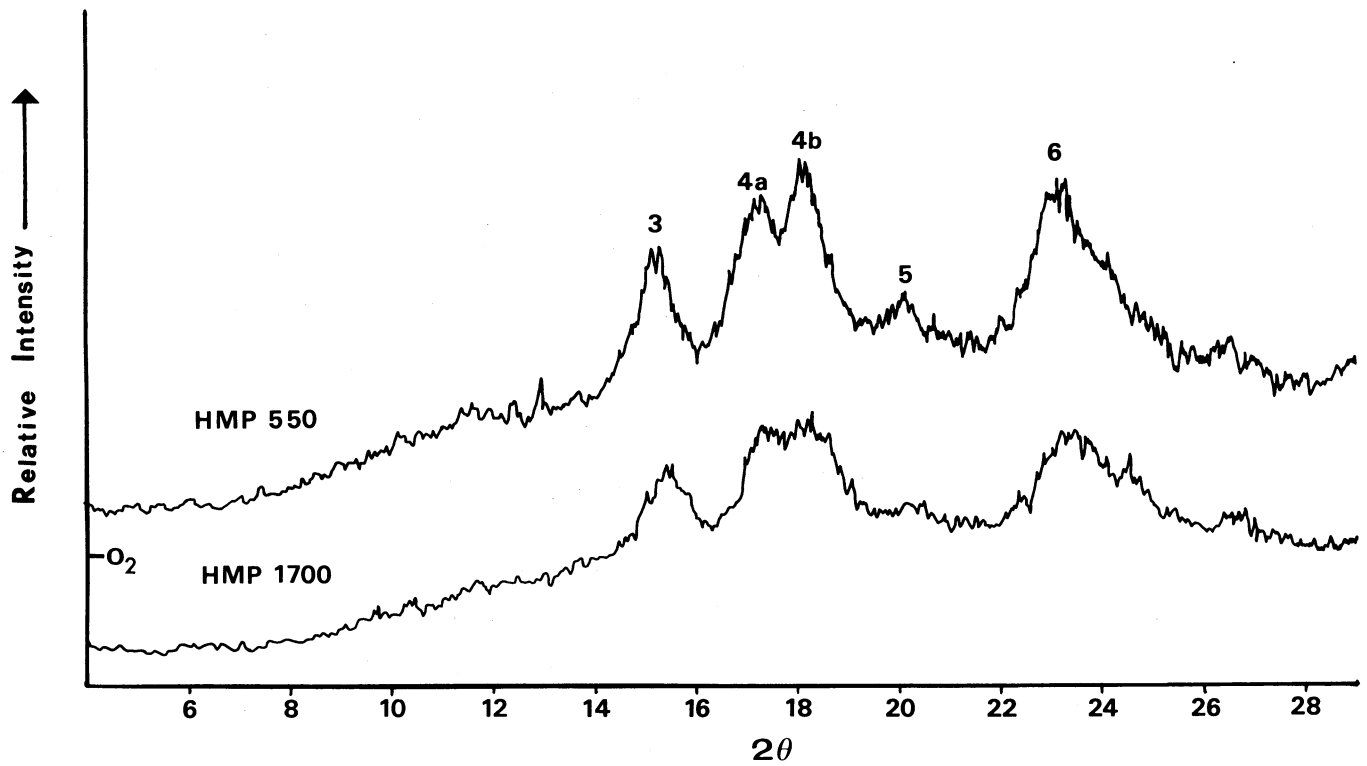

Fig. 1. X-ray diffraction patterns (CuKα) of millet starches.

patterns were determined for millet starches. At 65°C, the two RMP starches were significantly less swollen than the other starches (Table III). Swelling power at 70°C also tended to be lower for starches from RMP populations. From 80 to 90°C, RMP starches appeared to have the greatest swelling power, but those values were not significantly different from those of the other populations. Real differences in swelling power among starch populations may have existed; we feel that the method was not as precise as has been suggested (Leach et al 1959). Difficulties in obtaining good separations of supernatant from precipitated paste resulted in large standard deviations for swelling determinations at the higher temperatures.

Solubility patterns (Table IV) did not necessarily follow swelling power. For example, HMP550 and HMP1700 had high swelling powers but low solubilities at 75°C. From 75 to 90°C, starches isolated from RMP populations were significantly ($P < 0.05$) more soluble than the other starches, and at 95°C RMP'78 starch was the most soluble. In fact, at equal swelling, more solubles were leached from RMP starches than from the other samples (Fig. 2). In general, starches with low swelling and solubility at temperatures below 75°C had high swelling and solubility at temperatures from 80 to 95°C. This phenomenon could be related to the two-stage relaxation of bonding forces within the starch granules during swelling. Starch populations with low swelling and solubility during the first stage of relaxation would show higher values during the second stage.

The combined effects of swelling power and solubility on the pasting characteristics of millet starches were determined with the Brabender amylograph (Table V). The pasting temperature for all starches was 76.5°C. Among the various starches, the difference between the maximum and minimum values for viscosity at 95°C was 100 Brabender Units; the same was true for peak viscosity. Larger differences among starches were observed after 1 hr at 95°C and during the cooling cycle. HMP550 starch had the lowest viscosity at 50°C; RMP'78 had the highest. Furthermore, the change in viscosities between the heating (1 hr at 95°C) and the cooling cycle (viscosity at 50°C) was lowest for the HMP550 starch. Those data suggest that HMP550 starch tends to retrograde less than do starches from the other populations, which may be related, in part, to its tendency to solubilize less during heating (Table IV).

The contribution of starch molecules to the viscosity of a solution depends primarily on the particle volume they occupy (Van Holde 1971). Intrinsic viscosity primarily measures particle volume and resistance of molecules to displacement under conditions where associative bonding effects have been minimized (Leach 1963). Intrinsic viscosities of millet starches ranged from 1.47 to 1.71 (Table VI), with HMP1700 having the lowest and RMP '76 the highest. The range is lower than intrinsic viscosities reported for corn (Leach 1963) or sorghum (Freeman and Bocan 1973) and may reflect smaller molecular dimensions for millet starch molecules.

Pasting characteristics of various starches are affected by amylose and amylopectin contents as well as by their arrangement in the granule. Iodine affinity often is used to estimate amylose content of starches. Iodine affinities of pearl millet starches ranged from 4.13 to 4.75% (Table VI), which, when based on an iodine binding limit of 200 mg/g, suggests that amylose contents range from 20.5 to 23.5%. However, iodine affinities are not true indicators of amylose content because they depend on chain length and degree of branching (Bates et al 1943). Quantitative determinations of amylose by the blue value method (McCready and Hassid 1943) showed amylose contents ranging from 20 to 22% (Table VI). Badi et al (1976) reported a low amylose content for their millet starch (17%), but our data indicate that millet starches contain as much amylose as do normal cereal starches.

TABLE IV
Solubility (%) of Starches Isolated from Pearl Millet[a]

Temperature (°C)	Random Mating Populations				
	HMP550	Serere 3A	HMP1700	RMP'76	RMP'78
60	0.5 a	0.6 a	0.5 a	0.4 a	0.8 a
65	1.3 a	1.1 ab	1.1 ab	0.5 b	1.0 ab
70	1.8 a	2.9 ab	3.2 b	3.0 b	3.3 b
75	4.0 a	4.5 a	4.2 a	5.4 b	7.1 b
80	4.5 a	5.1 a	4.5 a	7.0 b	7.8 b
85	5.3 a	6.6 a	5.0 a	9.0 b	9.3 b
90	7.8 b	7.9 b	7.1 b	10.7 a	12.2 a
95	7.9 d	11.7 bc	8.7 cd	13.5 b	18.9 a

[a]Values represent the mean of three determinations. Within each temperature, values followed by different letters differ significantly ($P < 0.05$).

TABLE V
Amylograph Pasting Characteristics of Pearl Millet Starch[a]

Starch	Viscosity				
	at 95°C	Maximum	After 1 hr at 95°C	at 50°C	After 1 hr at 50°C
HMP1700	500	500	400	540	500
Serere 3A	440	440	440	620	580
HMP550	480	480	340	500	460
RMP'78	480	480	460	640	620
RMP'76	400	400	340	540	520

[a]Values are reported in Brabender Units.

TABLE VI
Intrinsic Viscosity, Iodine Affinity, and Amylose Contents of Pearl Millet Starches

Starch	Intrinsic Viscosity[a]	Iodine Affinity[b] (%)	Amylose[c] (%)
HMP1700	1.47	4.28	22.0
Serere 3A	1.54	4.13	21.0
HMP550	1.62	4.38	21.0
RMP'78	1.58	4.75	21.5
RMP'76	1.71	4.13	20.0

[a]Standard deviation = ± 0.05.
[b]Standard deviation = ± 0.04.
[c]Determined by blue value method of McCready and Hassid (1943).

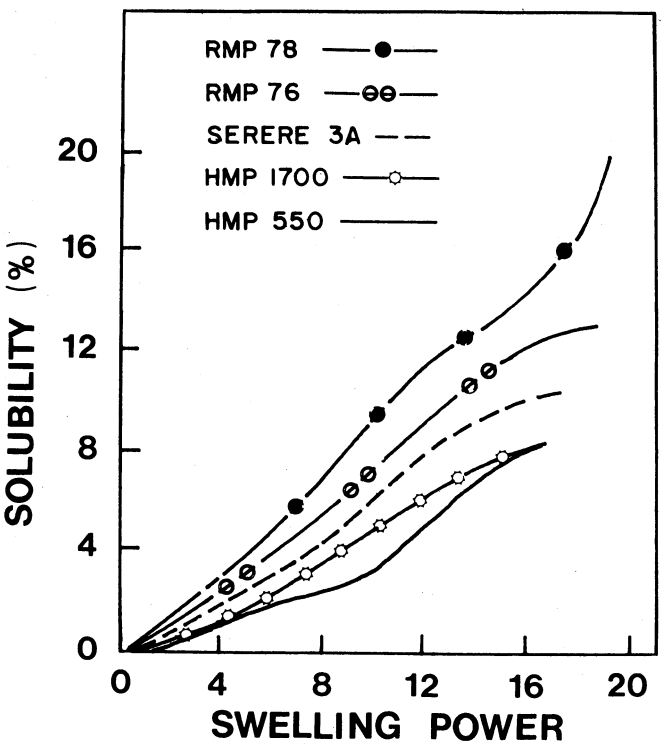

Fig. 2. Solubilities of millet starches at equal levels of swelling.

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