NOTE

Critical Moisture Content for Fissures in Rough Rice

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ABSTRACT

Determinations were made of the critical moisture content (CMC) in selected IR varieties and other rough rices after harvest in both dry and wet seasons at the International Rice Research Institute. Below the CMC, the grain becomes susceptible to fissuring. The rices were dried to moisture contents of 10–20%, wb, stressed by soaking in water for 2 hr, and redried before milling. Susceptible variety IR42 had a CMC of 16% in both crops, whereas resistant variety IR60 had a CMC of 14% in the dry season and 12% in the wet season. Grain for the moisture-adsorption stress test was shade-dried to 14% moisture, verified as optimum. The CMC obtained from dried grains, adjusted to higher moisture content by moisture adsorption before stressing, did not effectively distinguish among IR rices. Flash-drying of all freshly harvested grain to a target moisture content of 20 ± 5% may be employed without danger of grain cracking.

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Varietal differences in susceptibility to fissuring during moisture-adsorption stress was reported from: 1) the wide range of the minimum period required to fissure grains at high humidity (Kunze 1985); and 2) differences in head rice yield after soaking for 1–3 hr in room-temperature water (Srinivas and Bhashyam 1985). Shade-dried, freshly harvested Indian rough rices also differed in the critical moisture content (CMC), below 14–18% they become susceptible to fissuring (Srinivas et al 1978). International Rice Research Institute (IRRI) varieties also showed a wide range of tolerance for moisture-adsorption stress (Ibabao et al 1987). The variety IR42 was reported to be crack-susceptible in Muda estate, northern Malaysia, under combine harvesting (Anonymous 1984). No such complaint was observed in small holdings in the Philippines, where rice is seldom harvested overripe (manually by sickle). However, Gayanilo (1990) observed that IR64 was more tolerant to cracking than were IR42 and IR60 during sun-drying of rough rice at 1–6 cm thickness.

In the moisture-adsorption stress test adapted at IRRI, rough rice shade-dried to 14% moisture showed varietal differences in head rice yield of stressed grains, whereas those shade-dried to 16% had no reduction of head rice yield (Juliano et al, *in press*). The moisture-adsorption stress test involves soaking rough rice in 30°C water for 1–3 hr. By contrast, grains oven-dried at 35–40°C to a moisture content of 12% were all susceptible to cracking. Varietal differences were still observed.

Flash-drying of freshly harvested grain to 18% moisture has been proposed to minimize deterioration of the crop during the wet season when a limited drying capacity is available (de Padua 1986, NAPHIRE 1989a). The flash-dried grain can be stored for up to three months; final drying to 14% moisture can be done later (de Padua 1986, NAPHIRE 1989b). Thus, we wanted to verify the CMC of rough rices because of its importance in optimizing the water-stress test and in determining the target moisture content at which to end flash-drying.

MATERIALS AND METHODS

The freshly harvested rough rices of Basmati 370, CP/SLO 17, IR29, IR42, IR44, IR60, IR72, and IR74 were obtained from the 1990 demonstration plots (dry-season harvest in April-May; wet-season harvest in October-November) of the Plant Breeding, Genetics, and Biochemistry Division of IRRI. Moisture content (wet basis) was determined in duplicate with a Satake electrical-resistance grain-moisture tester (PB1D) calibrated with the oven method (based on the loss of weight after heating rice flour 1

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TABLE I
Head Rice Yield of Rough Rice Stressed by Soaking for 2 Hr in Water at 30° C[a]

		Moisture Content (%) from Desorption									
Variety	**Season**	**20**	**18**	**17**	**16**	**15**	**14**	**13**	**12**	**11**	**10**
IR42	Dry	52a	51a	51a	52a	49b	31c	17c	9cd	4ed	1e
	Wet	62a	62ab	62a	64a	59ab	56b	41c	26d	4e	1e
IR74	Dry	48a	49a	49a	46a	45a	24b	18bc	14cd	6de	2e
	Wet	54ab	53abc	55a	55a	48cd	47bcd	47d	27e	24e	15f
IR60[b]	Dry	53ab	45b	55a	51ab	55a	56a	45b	31c	20d	9e
	Wet	67a	66a	65a	66a	68a	67a	67a	63a	52b	35c
CP/SLO 17	Dry	52a	56a	44b	58a	56a	57a	57a	56a	53a	54a
	Wet	60a	59a	59a	59a	60a	58a	60a	58a	47b	40c
IR29	Wet	60a	61a	61a	63a	64a	62a	61a	60a	53b	51b
IR44	Wet	38b	45ab	43a	42ab	42ab	42ab	38b	31c	17d	11e
IR72	Wet	51ab	49ab	51a	51ab	48ab	47ab	45b	39c	28d	13e
Basmati 370	Wet	39ab	41a	41a	39ab	39ab	36ab	35ab	36ab	34bc	29c

[a] Means ($n = 2$) in the same line followed by the same letter are not statistically different at $P = 0.05$ by Duncan's (1955) multiple range test. LSD (0.05) = 8.0% (dry season) and 4.9% (wet season). Critical moisture content is underlined.
[b] Mean of two dry season samples for IR60, with CMC of 13 and 14%.

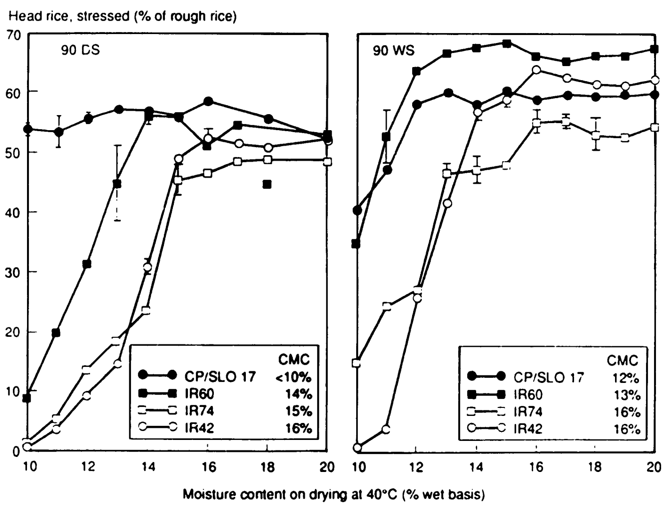

Fig. 1. Effect of moisture content (oven-dried freshly harvested rough rice) on head rice yield of four selected rices after moisture adsorption stress. 90 DS = rice obtained from demonstration plots, 1990 dry-season harvest. 90 WS = rice obtained from demonstration plots, 1990 wet-season harvest. CMC = critical moisture content below which head rice yield decreased.

hr at 130°C [AACC 1983]). Values ranged from 22 to 25%, wb. Lots of 30 g each were weighed and placed in a 40°C air oven. Duplicate lots were removed periodically for weighing until weights of 20, 18, 17, 16, 15, 14, 13, 12, 11, and 10% moisture, wb, were attained. The dried samples were placed in plastic bags, sealed, allowed to cool at ambient temperature, and tempered for two days.

Freshly harvested, oven-dried grains of CP/SLO 17, IR8, IR42, IR44, IR48, IR60, IR64, and IR72 at 10.7–12.2% moisture content were subjected to moisture adsorption in a cylinder over water under 0.5 atm of air pressure to accelerate moisture adsorption without fissuring (Satake 1991). Samples were weighed periodically until weights equivalent to moisture contents of 13, 14, 15, 16, 17, and 18%, wb, were attained. Duplicate grain samples were then transferred into plastic bags, sealed, and tempered for at least two to five days before subjecting them to the soaking stress test.

The moisture-adsorption stress test involved soaking duplicate rough rice samples for 2 hr in water at ambient temperature (30°C) followed by air-drying to 12% moisture. After two days of equilibration at 12% moisture, stressed grains were dehulled with a Satake THU 35A-type testing husker. Brown rice lots (5 g) were milled for 30 sec in a Kett Pearlest friction micromill. Head-milled rice (>.75 × length of whole milled rice) and brokens (<.75 × length of whole milled rice) were separated manually. Total and head rice yields were calculated as percent of rough rice. Hull percentage was also calculated. The initial control sample and unstressed moisture-adjusted grains were also milled after air-drying to 12% moisture content for comparison. The head rice data were subjected to analysis of variance and Duncan's (1955) multiple range test.

RESULTS AND DISCUSSION

CMC During Moisture Desorption

Analysis of variance showed that moisture content, variety, and moisture content × variety, but not replication, significantly affected head rice yield of stressed grain. Varietal differences in CMC were evident among selected IR rices and CP/SLO 17 in both seasons (Table I, Fig. 1). In the dry-season crop, CMC was 16% for IR42, 15% for IR74, 14% for IR60, and <10% for CP/SLO 17. The CMC values for the wet-season crop were 16% for IR42 and IR72; 14% for IR44 and IR74; and 12% for Basmati 370, CP/SLO 17, IR29, and IR60.

The CMC for IR44 and Basmati 370 may be too low because they were determined from the more resistant grains. The more susceptible grains were already fissured during postharvest handling, as reflected in the poor (<40%) head rice yield of unstressed grains (Table I). IR60 showed lower CMC than did IR42 in both crops, but CP/SLO 17 was better than most IR rices, particularly in the dry-season crop. Two dry-season samples of IR60 had CMC of 13 and 14%. Even at 10–14% moisture content, IR60 continued to have higher head rice yield after being subjected to stress than did IR42 and IR74 (Table I, Fig. 1). Evidently, varietal differences in crack resistance are still evident below the CMC. Hull percentage of the rough rices ranged from 19 to 24%. Total milled rice was 67–74% of rough rice weight. Srinivas et al (1978) reported slightly higher CMC (14–18%) of shade-dried Indian rices. CMC was 14% for a sample of U.S. long-grain rice (Siebenmorgen and Jindal 1986).

CMC During Moisture Adsorption

Control oven-dried grains (10.7–12.2% moisture, before moisture adsorption and soaking stress test) gave 33–60% head rice yield (Table II). Susceptible varieties IR8, IR42, IR44, and IR48 showed poor (33–39%) head rice yield. IR60, IR64, and IR72 had 45–47% head rice yield. CP/SLO 17 had 60% head rice yield. Head rice yields of IR42 and IR60 were lower than those of freshly harvested grain (Table I), probably because of drying below the CMC. Moisture adsorption treatment alone did not significantly decrease head rice yield, as shown by data for unstressed grains, except at 17% moisture in IR8, IR60, IR64, and IR72.

TABLE II
Head Rice Yield of Rough Rice Before and After Stress by Soaking for 2 Hr in Water at 30°C[a]

Variety	Control	Unstressed	Stressed With Adjusted Moisture Content (%) from Adsorption						
			12	13	14	15	16	17	18
IR8	39a	32–38	1e	4e	11d	21c	31b	30b	. . .
IR42	34a	31–35	2e	6d	17c	26b	33a	. . .	34a
IR44	35a	33–37	4f	10e	18d	23c	31b	31b	. . .
IR48	33a	27–33	. . .	3f	9e	16d	23c	28b	. . .
IR60	45a	40–47	19c	31b	34b	41a	41a	44a	. . .
IR64	47a	41–47	. . .	19d	29c	40b	39b	40b	. . .
IR72	47a	39–48	8e	18d	31c	39b	32c[b]	39b	. . .
CP/SLO 17	60a	59–62	47c	55b	59a	59ab	59a	. . .	60a

[a]Means ($n = 2$) in the same line followed by the same letter are not statistically different at $P = 0.05$ by Duncan's (1955) multiple range test. LSD (0.05) = 3.4%. Initial moisture content of 10.7–12.2% wet basis (control samples, before moisture adsorption). Critical moisture content is underlined.
[b]Mean head rice yields of unstressed moisture-adjusted samples of 41 ± 2%.

Analysis of variance showed that moisture content, variety, and moisture content × variety, but not replication, significantly affected head rice yield of stressed grain. Head rice yield of stressed grain was lowest for grain with 12% moisture, and it increased progressively with an increase in moisture content of the stressed grain. All three susceptible varieties (IR8, IR42, and IR44) had CMC of 16%; IR48 had CMC of >17%; and IR60, IR64, and IR72 had CMC of 15%. CP/SLO 17 had the highest head rice yield at any moisture content and had CMC of 14%. CP/SLO 17 had the lowest head rice yield (stressed) at 12% moisture. Thus, CMC obtained from grains with moisture adjusted by moisture adsorption did not differentiate among IR rices as effectively as did CMC obtained from grains with moisture adjusted by desorption. IR60 was no better than IR8, IR42, and IR44 in CMC obtained by moisture adsorption.

Adjusting moisture content by desorption is more convenient and faster than doing it by adsorption because of the risk of grain fissuring during moisture adsorption below the CMC. The CMC obtained by adsorption was higher than that obtained by desorption, except for IR42 (Tables I and II).

The results confirmed that the water-soaking test is best run on 14% moisture, shade-dried grains so that only the susceptible varieties (inasmuch as their moisture content is below their CMC) will decrease in head rice yield. Shade-drying ensures that the starting samples will have high head rice yield (>50%) to obtain reliable CMC based on the whole sample rather than on the resistant grains that escape cracking during sun- or oven-drying. At 13% moisture, the head rice of IR60 would be lower, but that of CP/SLO 17 would not be affected. Using oven-dried samples with equilibrium moisture content of 11–12% for the stress test results in reduction of head rice yields for all samples, but the resistant rices (14% CMC, such as IR60) will still have higher head rice yield than the susceptible varieties (15–16% CMC, such as IR42) at equilibrium moisture contents below 13% (Table I, Fig. 1).

Based on the CMC of susceptible varieties (15–16%) and the range in moisture content of harvest rice grain (mean ± 5%) (IRRI 1981, Chau and Kunze 1982), flash-drying to 20% moisture would not adversely affect the head rice yield of all IR rices. Only a few grains will have <16% moisture when mean moisture content is 20 ± 5%. Even if incipient parboiling occurs during flash-drying, drying precaution still has to be observed because parboiled rice is still prone to crack, although to a lesser degree than raw rice (Chattopadhyay and Kunze 1986).

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