Table 5. Biomass production of *Erythrina stricta* seedlings (d.wt. in g/plant) at different durations after sowing

Seed storage after 30 days	Age in days					
	15	30	45	60	75	90
Control	0.60 (±0.32)	0.67 (±0.48)	0.98 (±0.34)	1.38 (±0.47)	1.62 (±1.42)	1.97 (±1.32)
Neem leaf powder	0.66 (±0.47)	0.83 (±0.73)	1.21 (±0.83)	1.54 (±0.76)	1.87 (±0.68)	2.31 (±1.42)
Vitex leaf powder	0.54 (±0.74)	0.64 (±0.68)	0.83 (±1.32)	1.26 (±0.84)	1.56 (±0.76)	1.63 (±1.02)
Cowdung powder	0.46 (±0.53)	0.61 (±0.43)	0.87 (±0.78)	1.12 (±1.08)	1.26 (±0.64)	1.42 (±1.16)

(±) : S.D.

leaf-stored seeds (1.63 g/plant) and cowdung stored seeds (1.42 g/plant) (Table 5).

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KERNEL EXPOSURE AND MICROBIAL SPOILAGE IN PARBOILED RICE

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ABSTRACT

Kernel exposure due to husk opening in parboiling predisposes the parboiled paddy to microbial spoilage, heat development, breakage and loss in rice outturn during slow yard drying in humid rainy weather. When soaked paddy was steamed after addition of salt at 0.8 per cent (W/W) rice kernels were not exposed because the salt rendered closed grains to stay closed in parboiling. Salt treated closed grains offered protection to the rice kernel from mould invasion and withstood non-drying for seven days with superficial infection of moulds compared to the deeper infection in grains with exposed kernels. In a period of seven days of non-drying, parboiled paddy with exposed kernels sustained 51.2 per cent grain infection, yielded 57.8 per cent rice outturn with 55.2 per cent breakage, 18.6 per cent oil bran with a free fatty acid content of 34.9 per cent compared to 5.9 per cent grain infection, 67.5 per cent rice outturn with 11.4 per cent breakage, 28.9 per cent oil with 22.0 per cent free fatty acid in closed grains. Salt treatment to the opened grains at 0.6 per cent (W/W) level equivalent to the present in grains treated with 0.8 per cent salt offered only a slight protection indicating that it is the intactness of husk and non- exposure of kernels in closed grains that protect the rice kernel from spoilage than the protective action of salt.

KEY WORDS : Parboiled Rice, Kernel Ex osure S oila e

Paddy (*Oryza sativa L.*) is milled to yield rice as it is eaten as whole kernel and not as flour. Parboiling is the common method of processing paddy in India. Drying of parboiled paddy is accomplished by mechanical dryers in modern rice mills while the vast majority of conventional rice mills depend only on sun drying in yards. Although solar energy is available during most part of the year, at least for a period of 2-3 months during September- November, intermittent rains and cloudy weather and rain wetting cause severe damage due to microbial infection, heat development and discolouration leading to loss in rice outturn and lowering the quality of rice and the bran (Singaravadivel *et al.*, 1981a). Anthoni Raj *et al.* (1981) reported that the grain opening and exposure of kernels due to husk opening and splitting in parboiling predisposes the exposed kernel surface for moulds attack. The application of common salt was found to keep the grains closed in parboiling. Singaravadivel and Anthoni Raj (1983) indicated the disadvantages due to grain opening in parboiling. Although the prevention of husk opening and non-exposure of kernels in parboiling improved the milling characteristics, the extent of mould infection in conventionally parboiled opened grains and salt treated closed grains and the consequent losses in rice and bran have not been investigated in detail. The present work reports minimising infection and losses by prevention of exposure of rice kernels during slow or non-drying periods in humid rainy weather.

MATERIALS AND METHODS

IR 20 paddy soaked for three days in cold water was parboiled in a steaming kettle. This type of conventional parboiling caused husk opening and exposure of rice kernels in about 76 per cent grains, In lots of 50 kg each, husk opening was prevented by the application of 0.5, 0.8 and 1.0 per cent (W/W) market salt prior to steaming. Since these levels of salt prevented husk opening to almost an equal extent (6.3, 4.0 and 3.7% in 0.5, 0.8 and 1.0% salt respectively) paddy treated with 0.8 Per cent level recommended for adoption in regular processing (@ 0.5kg/bog of 60kg of raw paddy soaked) alone was taken up for detailed investigation.

The microbial contamination in grains was [illegible] grains (salt treated) and parboiled opened grains (no salt added-control I). As application of salt itself might offer some degree of protection against microorganisms, another 50 kg of parboiled husk opened grains was treated with 0.6 per cent (W/W) level of salt which was equivalent to the residual level of salt present in 0.8 per cent salt treated grains and maintained as an additional check (Control II). The grains were left in separate heaps inside a room with 80-90 per cent RH for 7 days without spreading and drying so as to pick up natural infection. At intervels of 2,4, and 7 days the moisture content of paddy and heat development in heaps were recorded. The moisture content was determined by drying 5 g of whole grains in an oven at 105°C for 24 h. Samples were drawn at these intervals and 10 g was dehusked and the grains showing opaque blotches which were chalky in nature in an otherwise translucent grain were counted and expressed as per cent grain infection. The total fungal and bacterial counts was determined by the standard serial dilution plate technique in rose bengal and nutrient agar media respectively. The different species of fungi were counted and expressed as per cent over the total mould count recorded at each interval. Another set of samples were shade dried and taken up for assessing the milling yield. The potential yield (outturn) of milled rice was determined by milling 150 g of paddy in a McGill Miller No.1 for 45 sec so as to simulate conditions of Engelberg milling adopted in traditional huller mills. The head rice yield and brokens were determined in the milled rice. The degree of parboiling in conventionally parboiled and salt-treated parboiled grains was compared in well milled rice by the sedimentation and alkali degradation tests (Zakiuddin Ali and Bhattacharya 1; 972; Bhattacharya and Zakiuddin Ali 1976). The oil content in bran and the free fatty acids in oil were determined in the bran obtained by milling 150 g of dehusked rice samples in McGill Miller No.1 to about 6.0 per cent (0.2%) polish adopting the standard methods (A.O.A.C., 1970).

RESULTS AND DISCUSSION

Grains with opened husk and exposed kernels contained a higher level of moisture than salt treated closed grains. Salt treatment prevented excessive moisture absorption by the kernel during steaming (Table 1). Further, the presence of salt on the husk surface extracted water from the soaked paddy and also from the parboiled paddy by the exosomotic action, which was evident from the water that drained out from the soaked paddy and also from the parboiled paddy. Anthoni Raj *et al.* (1981) reported that salt treatment resulted in excessive draining of water during the process of steaming itself.

The salt treated parboiled paddy exhibited a comparatively lesser degree of parboiling in sedimentation test. A sedimentation height of 2.8 and 2.6 mm was observed in 0.05 per cent Hcl for conventionally parboiled and salt treated parboiled grains against 2.5 mm in raw milled rice. On the other hand, in alkali degradation test, parboiled milled rice both untreated and salt treated grains showed disintegration at 1.1 per cent KOH while raw milled rice was not degraded. However the severity of parboiling in salt treated rice may vary in normal practice depending upon the steam pressure and duration of steaming employed in conventional mills.

After 7 days of slow drying (or non drying) there was slight reduction in the moisture content in all the treatments. The moisture reduction was relatively greater in parboiled opened grain (Control I) and parboiled opened grains treated with 0.6 per cent salt (Control II). It was only 3.8 per cent in closed grains (Table I). The reduction in moisture in the former two treatments might be due to the heat development observed in the grains.

The heat development observed in Control I and II was relatively higher than that observed in salt treated lot. The closed grains recorded a maximum of 45°C on 7th day only while opened grains in Control I and II recorded 56°C and 55°C respectively on the 2nd day itself while the ambient temperature was 25 ± 2°C. In the latter two cases there was a 5°C fall in temperature on 4th day with a subsequent rise on 7th day. It is apparent that the reduction in moisture content in opened grains might be solely due to the heat development while in closed grains the exosomotic action of salt alone might have reduced the moisture content. The addition of salt to opened grains was not found to withdraw moisture as effectively as in closed grains (Singaravadivel *et al.*, 1981b) and hence the moisture reduction in opened grains might be due to the heat developed than due to salt action. The varying degree of heat development observed in opened and closed grains might be due to the variation in the microbial infection. Micro organisms were also found to produce heat as a product of their metabolism (Seminiuk, 1954).

Table 1. Moisture content, heat development, grain infection and microbial load in husk opened and husk closed parboiled paddy during non-drying periods

Particulars	Treatments	Storage days			
		0	2	4	7
Moisture content (%)	Control	33.2	33.0	27.7	24.9
	Control + 0.6% salt	33.4	32.3	29.6	23.5
	Salt 0.8%	31.4	29.7	31.1	27.6
Temperature (°C)	Control	32	56	51	56
	Control + 0.6% salt	32	55	50	56
	Salt 0.8%	32	33	37	45
Fungi (10^5 g^{-1})	Control	0.9	36.5	60.4	510.6
	Control + 0.6% salt	0.7	44.8	70.5	420.6
	Salt 0.8%	0.7	23.9	57.9	344.6
Grain infection (%)	Control	0	0	19.3	51.9
	Control + 0.6% salt	0	0	9.5	31.9
	Salt 0.8%	0	0	1.3	5.9
Bacteria (10^5 g^{-1})	Control	19.5	21.7	22.4	31.8
	Control + 0.6% salt	15.1	18.8	20.5	27.8
	Salt 0.8%	15.1	13.5	30.7	33.1

The parboiled opened grains had a mould count of 0.9 x 10^5 CFU g^{-1} (on dry basis) just after parboiling which however rose in a dramatic way to 36.5, 60.4 and 510.6 x 10^5 CFU g^{-1} after 2,4 and 7 days respectively. Application of 0.6% salt to opened grains although showed a slightly increased fungal count at initial stages than opened grains without salt treatment (Control I) which showed a reduction on 7th day the mould count recorded in closed grains was 344.6 x 10^5 CFU g^{-1} as against 510.6 x 105 CUF g^{-1} in opened grains. Until 2 days when the moisture was high, there was only a superficial webbing of grains by hydrophytic *Mucor mucedo.* This species grew only superficially at higher moisture level but did not cause any localised kernel infection. However, when moisture of the grains declined mould of mesophytic nature viz., *Aspergillus flavus, A.fumigatus, A. candidus, A. sydowi, A. niger and Penicillium citrinum* established causing localised infection on the exposed kernel surface (Table 2). In closed grains as the rice kernel was completely concealed by the husk segments these organisms gained entry only through micropylar opening which took a longer time to effect infection and thus narrowed down the degree of infection. The bacterial flora also multiplied on grains. It was lesser in opened grains compared to closed ones which might be due to higher competition by fungi in opened grains than in closed grains.

Fungi caused localised lesions on rice kernel rendering the gelatinized transluscent starch to turn opaque and friable with a chalky appearance. Examination of duhusked grains showed a higher level of grain infection in opened grains than in closed grains. After 4 days of slow drying there was 19.3 per cent grain infection in opened grains whereas it was 9.5 per cent in opened grains treated with 0.6 per cent salt and only 1.3 per cent in closed grains. After 7 days only 5.9 per cent infection was observed in closed grains as against 51.9 per cent in opened grains. The grain infection was 31.9 per cent in opened grains treated with 0.6 per cent salt. This clearly revealed that the application of salt to keep grains closed in parboiling provided a two pronged defence to the kernel by (i) non-exposure of kernel to infection and (ii) protective action *per se.* The protective action of salt is almost redundant to the advantages achieved by the intactness of husk segments.

The presence of higher level of fungi in opened grains than in closed grains while the bacterial count was almost similar, suggests that the damages in parboiled paddy is predominantly due to moulds. Because their cells multiply by fission and not by elongation as in fungi and because they are independent of another, bacteria are incapable of penetrating the intact grain tissues and cause any visible damage as fungi. With the increase in fungal multiplication, there was significant increase in breakage and loss in the outturn. The out turn and head rice yield was higher in closed grains due to a lesser breakage than that in opened grains or opened grains treated with 0.6% salt. Since the kernels have been concealed by husk in closed grains, deeper penetration by fungi into the kernel

Table 2. Proportion of different fungal contamination (10^5 g^{-1}) in husk opened and husk closed parboiled grains

Days to non-drying	Treatments	*A. flavus*	*A. fumigatus*	*A. candidus*	*A. sydowi*	*A. niger*	*Mucor mucedo*	Others	Total
0	Control	1.3	2.0	1.2	2.4	0	0.6	0	7.5
	Control + 0.6% salt	1.0	2.0	1.4	2.0	0	0.7	0	7.1
	0.8% salt treated	0.8	2.0	1.2	2.4	0	0.8	0	7.2
2	Control	12.4	2.9	1.5	2.2	0	17.5	0	36.5
	Control + 0.6% salt	20.6	5.8	2.7	1.8	1.3	12.6	0	44.8
	0.8% salt treated	20.5	1.7	2.4	3.5	1.0	5.6	0	34.7
4	Control	22.9	10.9	5.5	6.7	0	13.9	0.6	60.4
	Control + 0.6% salt	21.2	21.2	6.3	6.3	0.7	14.1	0.7	70.5
	0.8% salt treated	25.1	11.7	4.5	5.0	0.6	8.4	0.6	55.9
7	Control	224.7	132.7	20.4	66.4	0	66.4	0	510.6
	Control + 0.6% salt	202.0	96.8	21.1	46.3	0	50.5	4.2	420.6
	0.8% salt	165.3	62.0	31.0	41.4	3.5	37.9	3.5	344.6

Table 3. Changes in yield of milled rice, breakage, oil and free fatty acid content of husk opened and husk closed parboiled IR 20 paddy during non-drying periods

Particulars	Treatments	Storage Days			
		0	2	4	7
Milled rice (%)*	Control	70.3	64.0	61.2	57.8
	Control + 0.6% salt	70.3	67.3	65.7	61.1
	0.8% salt	70.4	70.1	68.7	67.5
Breakage (%)*	Control	1.4	33.6	46.2	55.2
	Control + 0.6% salt	2.8	17.7	28.1	43.8
	0.8% salt	2.0	1.7	9.1	11.4
Oil in bran (%)* (dry basis)	Control	32.1	26.3	18.8	18.1
	Control + 0.6% salt	32.3	27.5	24.5	18.6
	0.8% salt	32.0	30.5	30.6	28.9
Free Fatty Acids* (FFA %)	Control	5.2	37.9	40.9	34.9
	Control + 0.6% salt	3.8	22.1	17.7	22.5
	0.8% salt	2.5	7.7	21.3	22.0

** Significant at 1% level

CD (P=0.05) Milled rice 0.20; Breakage 0.08; Oil 1.44; FFA 6.80

did not occur where as in the opened grains exposed kernels served as a substratum for deeper invasion. This resulted in increased loss of outturn and reduced head rice yield due to breakage. Since salt offered some degree of protection, there was a relatively lesser loss in the outturn of 0.6 per cent salt treated opened grains (Control II) compared to untreated opened grains (Control I).

The microbial infection in general significantly reduced the oil content in bran and increased the free fatty acids (FFA) in oil. In bran from closed grains there was no significant reduction in oil content upto 4 days compared to that of opened grains (Table 3). The FFA increased rapidly in the opened grains attaining a level of 40 per cent in 7 days whereas in closed grains, it only rose upto 20 per cent over the same period. In salt treated opened grains it increased to 25 per cent. There might have been a neutralizing effect of salt itself since the increase in FFA was not as high as in opened grains although the infection was similar to that in 0.6 per cent salt treated grains. The liberation of FFA might have been due to the lipases of microbial origin as the inherent lipase might have been inactivated in parboiling as reported by Shaheen *et al.* (1975).

The closed nature of grains in 0.8per cent salt treated parboiled paddy caused the natural husk cover to remain intact and offerred a protection to the kernel against microbial invasion. The concealed nature of the kernel and the protective action of salt might act synergistically to protect the grains from spoilage.

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