LIMITED MOISTURE CANNING OF RICE—EFFECTS OF CROSS-LINKING

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ABSTRACT

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White rice was cross-linked with epichlorohydrin, whereas samples of its parboiled counterpart were cross-linked with either epichlorohydrin, sodium trimetaphosphate, or phosphorous oxychloride. Treated, as well as control, samples were canned under dry-pack conditions. Half the samples were precooked prior to canning. The other half were placed in the cans with an appropriate amount of water to give a final moisture content of about 60%. This resulted in two methods of rehydration. Epichlorohydrin-treated white samples and epichlorohydrin- and sodium trimetaphosphate-treated parboiled samples performed exceedingly well under dry-pack canning conditions. Precooking prior to canning appeared to offer a superior product. Treated samples were considered less sticky than untreated.

Canning procedures for rice generally follow the so-called wet-pack or dry-pack procedures. Wet-pack is defined as a canned rice product in which there is an excess of liquid media, such as in soups. Therefore, it follows that dry-pack is a canned product with the rice grains devoid of free or excess moisture. The objective of the dry-pack method is to provide sufficient moisture for gelatinization of the rice starch during retorting without causing pastiness or cohesion of the kernels. Generally, the rice is precooked prior to placing in the cans and retorting. This is done to avoid excessive cohesiveness of the canned

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grains. However, in the case of fried rice the in-can rehydration method is often used. The appropriate amount of water and other ingredients are added to give a final moisture content of about 60%. The cans are sealed and retorted, during which process the desired rehydration of the rice occurs.

Parboiled rice performs better than raw white rice in both wet- and dry-pack canning. White rice cannot be canned under wet-pack condition in any acceptable manner. Roberts *et al.* (1), however, used the dry-pack method for canning white rice. Nevertheless, the rice tended to clump when sterilized, making the kernels difficult to separate when the cans were opened. Ferrel *et al.* (2) and Ferrel and Kester (3) minimized the problem to some extent by the use of surfactants. Verity and Allen (4) claimed to have solved the problem by freezing and thawing the rice after canning, which reduced the clumping of the product.

Recently, Rutledge *et al.* (5,6) and Rutledge and Islam (7) reported that cross-linking the starch in rice resulted in improved resistance to thermal degradation during excess-moisture canning. Consequently, the rice was found to be less pasty and cohesive due to reduced starch leaching. Thus, the question arises as to the suitability of the cross-linked rice for in-can rehydration and the precooking method of dry-pack canning.

MATERIALS AND METHODS

Rice Modification

Due to the reduced severity of thermal processing of rice under limited moisture conditions (dry-pack) as compared to excess moisture conditions (wet-pack), the rice samples (Bluebelle) were cross-linked at lower levels than previously described (5,6,7). The levels used were reduced to 0.2% (w/w) for epichlorohydrin and sodium trimetaphosphate and to 0.084% for phosphorous oxychloride. All other conditions in the modification procedures were the same as reported earlier.

Canning

The rice samples were canned under limited moisture conditions (dry-pack) in 307 × 113 C-enameled cans by two different methods, as follows:

Method I

White Bluebelle rice (150 g) was cooked in 1 liter of water at 95° C (tap water adjusted to pH 6.0 with dilute acetic acid) over a low flame for 28 min until well-done. After being allowed to drain for 10 min on a 1.68-mm wire-mesh screen, the cooked rice weighed 536.7 g; this was equally divided into five cans which were sealed and retorted at 115.6° C for 60 min. Thus, 30 g of dry rice had consumed 77.3 ml of water.

Cooked under similar conditions, 30 g of epichlorohydrin-treated white rice was found to consume only 60.1 ml of water. Hence, 17.2 ml of water (pH 6.0) was added to each can prior to sealing to make up the moisture difference between samples.

Parboiled Bluebelle had to be cooked for 35 min to attain desirable doneness; 30 g consumed 79.2 ml of water. Parboiled Bluebelle modified with epichlorohydrin, phosphorous oxychloride, and sodium trimetaphosphate consumed 63.4, 64.8, and 68.2 ml, respectively. So, before sealing the cans, calculated amounts of water (pH 6.0) were added to make the moisture content equal that in the parboiled control.

Method II

In this method, no cooking or blanching was involved prior to canning. Thirty grams of rice sample was directly weighed into each of the 307×113 C-enameled cans and then a calculated amount of water (pH 6.0) was added as in Method I.

Evaluation

Two sets of taste panel evaluations were performed with the modified rice samples canned under limited moisture conditions. The first set included epichlorohydrin-treated white Bluebelle *vs.* untreated white Bluebelle control; the second set involved all parboiled samples treated by the three cross-linking reagents in conjunction with a control parboiled sample. There were five cans per treatment combination which were individually scored by 10 judges for color, cohesiveness, off-flavor, and doneness using a five-point hedonic scale similar to that described by Batcher *et al.* (8). The first set of data was analyzed as a 2×2 factorial in a randomized block design using judge and sample as replication. The second set of data was analyzed as a 2×4 factorial in a randomized block design using judge and sample as replication.

RESULTS AND DISCUSSION

The mean hedonic scores for white rice are presented in Table I. The analysis of variance revealed that treatment was highly significant ($P < 0.01$) in color, cohesiveness, and doneness. Flavor was not significant. Method of canning was highly significant in color and cohesiveness. The treatment $\times$ method interaction was found to be highly significant in cohesiveness and doneness. Thus, upon examination of means for cohesiveness, it was evident that the method of canning had less influence on cohesiveness scores with treated rice than with untreated rice. In color, there was a difference in magnitude as well as a difference in direction. The reason is not apparent why the judges found untreated white rice canned by Method II whiter than that canned by Method I. From the overall standpoint, it was obvious that Method I (*i.e.*, cooking or blanching prior to canning) was superior to Method II, in which the rice was directly weighed into

TABLE I
Treatment Means for Hedonic Scores[a] of Dry-Pack Canned White Rice

Canning Method[b]	Treated White		Untreated White	
	I	II	I	II
Color	4.86	4.44	3.22	4.16
Cohesiveness	4.94	4.82	3.56	1.58
Flavor	4.42	4.30	4.22	4.44
Doneness	4.44	3.38	2.42	1.46

[a]For color, cohesiveness, and flavor, a score of 5 was excellent, whereas for doneness, 3 was excellent and a score of 5 or 1 was considered underdone or mushy, respectively.
[b]Method I: blanching rice prior to canning; Method II: in-can rehydration.

the can and processed with a measured amount of water.

Treatment means for the hedonic scores associated with modified parboiled samples canned under limited moisture conditions are given in Table II.

Analysis of variance for color, cohesiveness, and doneness showed that treatment, method, and treatment × method interaction were highly significant ($P < 0.01$). Treatment and method were found nonsignificant with regards to flavor, thus indicating that neither treatment nor method of canning had any adverse effects on flavor. It was apparent, however, that the use of blanched rice resulted in a higher-quality canned product.

Since three cross-linking reagents were used in modifying the rice, appropriate orthogonal comparisons were made to isolate differences between treatments. Flavor rating was excluded in these comparisons because treatments were not significant with respect to flavor. F values for the orthogonal comparisons are given in Tables III and IV.

According to the first comparison in Method I (Table III) all the modified samples were better than the controls as far as color, cohesiveness, and doneness were concerned. Comparing samples modified with phosphorous oxychloride and those modified with epichlorohydrin and sodium trimetaphosphate, cohesiveness appeared to be of less importance; color and doneness were highly significant and significant, respectively. From the means in Table III, it was obvious that phosphorous oxychloride-modified samples were inferior to other modified samples. No significant difference was obtained between the samples

TABLE II
Treatment Means for Hedonic Scores[a] of Dry-Pack Canned Parboiled Rice

Canning Method[b]	Parboiled Control		Phosphorous Oxychloride		Epichlorohydrin		Sodium Trimetaphosphate	
	I	II	I	II	I	II	I	II
Color	3.50	2.88	4.22	3.80	4.70	4.54	4.26	3.92
Cohesiveness	3.24	1.58	4.70	4.04	4.94	4.76	4.78	4.26
Flavor	4.26	4.30	4.76	4.48	4.72	4.56	4.76	4.62
Doneness	2.40	1.62	3.22	2.96	3.40	3.52	3.48	3.36

[a]For color, cohesiveness, and flavor, a score of 5 was excellent, whereas for doneness, 3 was excellent and a score of 5 or 1 was considered underdone or mushy, respectively.
[b]Method I: blanching rice prior to canning; Method II: in-can rehydration.

TABLE III
F Values for the Orthogonal Comparisons (Method I)

Blanched Rice	Color	Cohesiveness	Doneness
1 *vs.* 2, 3, 4[a]	304.54**[b]	307.63**[b]	131.59**[b]
2 *vs.* 3, 4	53.11**[b]	2.85	6.06*[c]
3 *vs.* 4	1.32	2.14	0.60

[a]1 = Parboiled control, 2 = phosphorous oxychloride, 3 = epichlorohydrin, and 4 = sodium trimetaphosphate.
[b]** = $F_{0.01}$ with 1 and 27 d.f. 7.68.
[c] * = $F_{0.05}$ with 1 and 27 d.f. 4.21.

TABLE IV
F Values for the Orthogonal Comparisons (Method II)

Unblanched Rice	Color	Cohesiveness	Doneness
1 *vs.* 2, 3, 4[a]	449.40**[b]	963.99**[b]	384.31**[b]
2 *vs.* 3, 4	50.73**[b]	24.61**[b]	27.42**[b]
3 *vs.* 4	79.09**[b]	20.88**[b]	3.18

[a]1 = Parboiled control, 2 = phosphorous oxychloride, 3 = epichlorohydrin, and 4 = sodium trimetaphosphate.
[b]**$F_{0.01}$ with 1 and 27 d.f. 7.68.

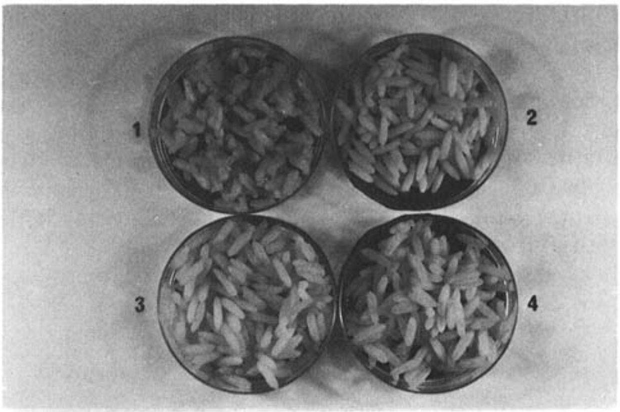

Fig. 1. Limited moisture canning of parboiled rice (Method I). 1 = Parboiled control, 2 = epichlorohydrin, 3 = sodium trimetaphosphate, and 4 = phosphorous oxychloride.

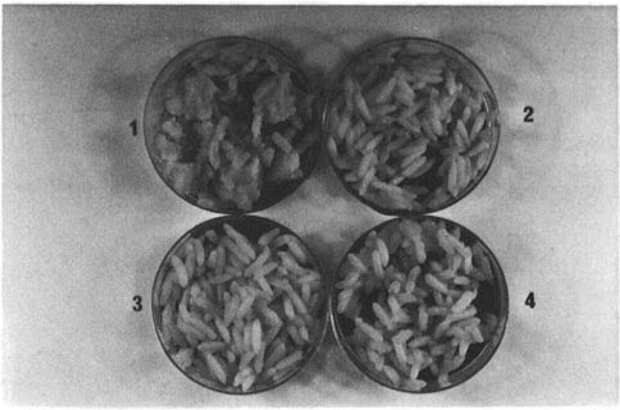

Fig. 2. Limited moisture canning of parboiled rice (Method II). 1 = Parboiled control, 2 = epichlorohydrin, 3 = sodium trimetaphosphate, and 4 = phosphorous oxychloride.

treated with epichlorohydrin and sodium trimetaphosphate. Figure 1 illustrates the differences among all the parboiled samples canned under limited moisture by Method I.

With the second method of canning using unblanched rice, as shown by the orthogonal comparisons in Table IV, highly significant differences were obtained in all cases except for doneness between epichlorohydrin- and sodium trimetaphosphate-treated samples. Comparing means from Table III, it was evident that the modified samples were superior to the control. Similarly, the epichlorohydrin- and sodium trimetaphosphate-treated samples were superior to that treated with phosphorous oxychloride. In considering color and cohesiveness, epichlorohydrin-treated samples appear superior to sodium trimetaphosphate-treated samples. Figure 2 illustrates the differences among parboiled samples canned under limited moisture without any prior cooking or blanching.

Both studies with white and parboiled rice indicated that Method I (*i.e.*, cooking or blanching prior to canning) was superior to Method II, in which the rice was totally rehydrated in the can. However, it should be emphasized that the treated rice samples canned by Method II were always superior to the control samples, regardless of the method of canning. Also, from an economic or labor standpoint, Method II (in-can rehydration) may offset the slight advantages with regard to overall quality evidenced in the blanched samples.

The effects of cross-linking on the nutritional properties of canned rice have not been examined at present.

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