THE EFFECT OF SOME PROCESSING VARIABLES
ON THE CANNING STABILITY OF RAW AND
PARBOILED LONG-GRAIN RICE VARIETIES

A Thesis

By

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CHAPTER I

INTRODUCTION

Rice (Oryza sativa L.) supplies food for a greater number of human beings than any other known plant. Within the last century, it has become commonplace in the Western diet. Its utilization is constantly increasing in the form of convenience foods such as canned soups.

Before the development of commercial parboiling in the 1940's, the texture of canned rice in liquid media such as soups was largely unacceptable. The development of parboiled rice of adaptable types has enabled canners to produce commercially acceptable products. While parboiled rice does not disintegrate as readily as does raw rice, there are still pronounced losses of textural qualities during the canning process. The alleviation of such textural losses could inspire further acceptance of canned rice products on the American market.

It appears that optimum processing conditions are influenced mainly by variety and parboiling treatment and in a minor way by other technological variables. This investigation concerns varietal differences and the quantitative effects of parboiling, pH, calcium lactate salt concentration, and blanch time in terms of textural qualities of canned rice.

CHAPTER II

LITERATURE REVIEW

Historical

Rice was first grown over 5,000 years ago in the old world tropics including China and Eastern and Southern Asia. It originated from a wild species that resembled modern rice in the Asia-India region. Rice was introduced into the United States in South Carolina in 1685 and spread from there (12). Texas production started about 1860, but was not of commercial importance until 1905 (11, 18).

Over seven billion bushels of rice are harvested throughout the world annually. The annual per capita consumption may run as high as 400 pounds in parts of Asia while about seven pounds is the United States average (2, 24).

Varieties

Commercial varieties of rice grown in the United States are grouped into short, medium, and long-grain categories. All three are in demand and are marketed for various culinary purposes. At the present time, specific long-grain varieties are preferred for use in most canning formulations. These late maturing, long-grain varieties are Rexoro, Texas Patna, and TP 49. Other commercially produced long-grain varieties have not been so readily adaptable for canning. Jojutla, a Mexican variety, shows superior textural properties which are presently being genetically utilized to develop adapted United States varieties (25, 29).

Processing Characters

The desired canned rice product is white with separate non-cohesive kernels and a minimum amount of longitudinal splitting and fraying of edges and ends. The canning liquor should be clear (17, 26).

The textural quality of canned rice may be influenced by varietal differences, chronological age of the grain, parboiling treatment and other variables and techniques of processing technology. Varietal differences have been attributed, at least partially, to variations in amylose content (17, 29, 31). Aging differences are likely caused by changed colloidal properties of the grain and cell wall during storage (5, 6). Processing variables such as salt concentration, pH, fat content, and blanch time have shown varying effects on cooked and canned rice texture (7, 9, 14, 26, 29).

According to Kester (17) parboiled rice, unlike white rice, does not disintegrate when submitted to canning process times and temperatures in a limited moisture medium. However, the optimum parboiling conditions for various varieties of rice for canned products have not been clearly defined. Jones *et al*. (13) have indicated that a severe steam treatment of 10 minutes or longer at 15 psi gives best results.

White rice process. Roberts *et al*. (26) have developed a process for canning white rice. Quite unlike the processing of liquid or semi-liquid formulations, their process utilizes limited moisture to minimize kernel disintegration and a soak period to help prevent clumping of kernels. They also reported that alkaline canning solutions caused kernel yellowing. The addition of acid had little effect except that concentrations of 0.01 percent or less of acetic acid improved color and flavor. Citric acid produced off-flavored and rubbery grains.

Effect of emulsifier. Rice canned in accordance with Roberts' method tends to clump when sterilized, thus making the kernels difficult to separate when the cans are opened. Ferrel et al. (7) overcame this problem through the use of emulsions and emulsifying agents. A rinse treatment with dilute emulsions or dilute dispersions of surface active agents during the canning procedure markedly reduced the cohesion that normally develops in the product. Neither type nor concentration of an emulsifier in a particular emulsion significantly affected the cohesiveness. There were, however, differences in cohesiveness when the emulsifiers were used alone.

Effect of salts. From cooking tests, Ghosh and Sarbar (9) reported that inorganic salts may either increase or decrease the water uptake of rice and that sloughing or loss of grain material during cooking was also affected. Magnesium sulfate increased water uptake; calcium chloride decreased it; and magnesium chloride had little effect. Sodium chloride and sodium sulfate would either increase or decrease water uptake depending on concentration. Loss of grain material during cooking was lessened by sodium chloride, sodium sulfate, calcium chloride, and magnesium chloride, but not by magnesium sulfate (9).

Analytical Techniques

Papers concerning the culinary properties of raw rice abound, but literature relating properties and quality of canned rice are limited. However, it is logical, since the canning process is essentially cooking, that methods and techniques for the analysis of either should be applicable to both.

Texture. Dawson *et al.* (4) reported a high positive correlation between the water uptake ratio (cooked weight divided by weight before cooking) and cohesiveness. Long-grain rice took up more water and was less cohesive than short or medium grain varieties. Similarly, Little and Hilder (21) found the alteration of rice starch during heat treatment to be directly related to the cohesiveness of cooked rice samples. The rice with highest heat alteration values was found most cohesive by a taste panel.

Wigman *et al.* (30) were able to utilize the phase contrast microscope to examine rice starch for granule size, stage of hydration during cooking and granule disruption. Their technique has been used to determine the proper cook treatment. Similarly, microscopic studies by Little and Dawson (22) revealed that different patterns of swelling and disruption may be caused by delaying or limiting effects of non-starch components.

The L.E.E.-Kramer Shear Press (now manufactured by the Allo Engineering Company as the Allo-Kramer Shear Press) has proven valuable as a tool for the objective measurement of firmness of rice and textural qualities of many foods (19). Its use in the determination of maturity of raw peas, lima beans, and southern peas, as well as the firmness of raw or canned apples, beets, spaghetti, chicken, beef, and shrinp has been established (19, 23). Presently, at least two large food manufacturers are using the shear press to objectively measure the texture of rice products (14, 29).

Composition. The amount of starch in the cooking water was found to be independent of grain type by Batcher et al. (3). However, the total solids were significantly lower in the liquid in which long-grain varieties were cooked.

Halick and Keneaster (10) have reported a positive correlation between the soluble amylose content and the quality of rice in cooking tests. The iodine blue reaction with amylose is used to obtain a spectrophotometric index which relates to the soluble amylose fraction. Roberts et al. (27) utilized the iodine test as a method for the determination of severity of treatment of parboiled rice. They theorized that more severe parboiling treatments would enhance the breakdown of starch granule structure. This breakdown would result in more readily dissolvable amylose which would give higher iodine values.

A method of quality determination which is of importance in the evaluation of small amounts of breeding material is the alkali digestion test as described by Little et al. (20). Quality is indicated where kernels exhibit resistance to spreading or when spread exhibit clear rather than opaque masses.

The Curbell turbidity tester as described by Kertesz (15) has been utilized as an instrument for rapid turbidity determination. It is especially useful in measuring the clarity of fruit juices and the canning liquor of vegetables and other foods where turbidity is an important aspect of quality. Kertesz stated that of 17 different samples of canned pea liquors, the maximum variation between readings on the same sample was 0.25 unit.

Color. The Gardner Tristimulus Color and Color Difference Meter accurately relates differences in color between samples and a calibrated standard plate. The "L" scale measures lightness, the "a_L" scale measures redness when positive and greenness when negative and the "b_L" scale measures yellowness when positive and blueness when negative (1). This instrument has been applied to many products including paints, leathers, textiles, and foods. Younkin (32) was able to measure differences in tomato puree which trained observers were not able to detect. Roberts *et al.* (27) utilized the instrument to relate the color of parboiled rice to the severity of treatment.

In summary, several diverse techniques have been employed in the preparation and evaluation of rice material. All workers are in agreement that long-grain rice generally exhibits more desirable soup canning qualities than the other grain types grown in the United States. These reports, however, do not provide definite information appertaining to canned rice in a liquid medium. This study was conducted to provide basic information concerning canned white and parboiled long-grain rice in terms of the fundamentals involved. Specifically the objectives were: to determine the canning characteristics of various varieties of white and parboiled rice for specific uses; to evaluate the effect and interaction of varieties and processing variables upon canned rice; and to formulate optimum processing treatments for rice in a liquid medium.

CHAPTER III

MATERIALS AND METHODS

Selection of Material

Long-grain rough rice samples of Jojutla, Century Patna 231, Belle Patna, and Texas Patna varieties were obtained from pure one-year old stocks at the Rice-Pasture Research and Extension Center, Beaumont, Texas. Belle Patna and Texas Patna are commonly used for commercial canner quality parboiled rice. Jojutla, a variety introduced from Mexico, exhibits superior canning qualities and is presently being employed in breeding programs as a source of desirable canning characters. Century Patna 231 serves as a negative control because it is completely unsuited for the specific uses to which this study pertains.

Parboiling

The parboiling of samples was conducted at the Beaumont center in a small upright retort especially constructed for this purpose. The only variation in the parboiling procedure was the steam treatment which included 0, 2.5, 5, 10, and 15-minute intervals. The procedure in outline form is as follows:

1. Ten sample trays each with 150 grams of rough rice were put into the retort.
2. Vacuum was applied for 30 minutes and the pressure was recorded.

3. After completion of the vacuum treatment, the retort was filled with water preheated to 150° F. and pressurized to 75 psi.

4. The rice was steeped at 150° F. and 75 psi for two hours to bring the moisture content to approximately 35 percent. While the rate of hydration for all rice varieties is not constant, two hours of steeping will bring the varieties used in this study close to the desired 35 percent.

5. After steeping, the pressure was released and the water drawn off.

6. The rice was steamed at 250° F. for either 2.5, 5, 10, or 15 minutes.

7. After steaming, the samples were placed in drying trays, examined for ruptured kernels and dried slowly at room temperature to approximately 12 percent moisture.

Milling

The dry parboiled rice was hulled in a McGill Sample Sheller to remove most of the hulls. Complete removal was effected during milling. Milling was accomplished in a McGill miller which could accommodate a 1,000 gram sample. Two 30-second runs were made with two pounds of force followed by 30 seconds of polishing with no weight on the miller. Ground limestone was used during the milling process to absorb oil extracted from the embryo and bran layers. After milling, the rice was placed into cans which allowed equilibration of the moisture driven off by milling, thus preventing further cracking of kernels. The broken rice was separated from the head rice which was stored in air permeable containers until canned.

Determination of Parboiling Degree

The method of Roberts et al. (27) was utilized to show differences in degree of parboiling attributed to variations in time of steam treatments during the parboiling process. Iodine blue ratings were obtained at the Beaumont center in accordance with the procedure as outlined by Roberts et al. (27) except that a Bausch and Lomb Spectronic 20 Colorimeter was used instead of the Klett-Summerson instrument. To further corroborate differences in treatment, color readings were taken with the Gardner Color and Color Difference Meter.

Canning

The raw and parboiled rice was canned according to the following method:

1. Weigh out 150 grams of rice and blanch in tap water at 205° F. for 10, 15, or 20 minutes.
2. Cool in running water.
3. Divide the blanched rice into nine equal aliquots and fill into nine no. 300 cans.
4. Fill the cans with cold distilled water, or 0.25 percent or 0.50 percent calcium lactate solutions which have been adjusted to pH 4.5, 6.5, or 8.5 with acetic acid or sodium hydroxide. All combinations of these variables were canned.

5. Seal and retort for 30 minutes at 250° F.
6. Cool quickly in running tap water.
7. Store for at least one week and evaluate.

Evaluation

The evaluation procedure was carried out in the research laboratory of Uncle Ben's Inc., Houston, Texas.

1. Turbidity. The Curbell Turbidity Tester (Figure 1) was utilized for two readings which gave insight to turbidity caused by the soluble fraction as well as the sloughed material. Each can was opened undisturbed; the liquor was poured into the tester for the first reading, T_1; the can was shaken vigorously 20 times and the second reading, T_2, was taken. It was necessary to modify the Curbell Turbidity Tester for the second reading (Figure 2). A triangular shaped wooden wedge which reduced by half the depth of the instrument was employed to gain more sensitivity in the scale for the more turbid liquid material.
2. Drained weight. The rice was emptied from the can into a strainer which was set on a towel to effect good removal of excess moisture. The drained weight was then recorded to the nearest 0.1 gram utilizing a Mettler balance.
3. Color. The Color and Color Difference Meter was employed to measure differences in color due to variety and treatment. Water was poured into the optically correct testing cup to an

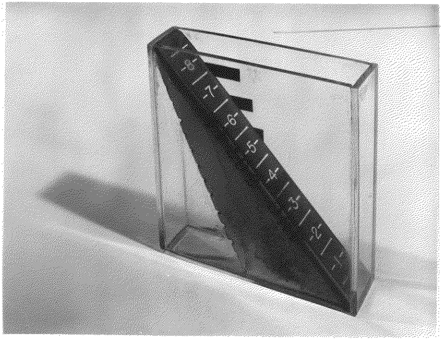

Figure 1. Unmodified portion of Curbell Turbidity Tester.

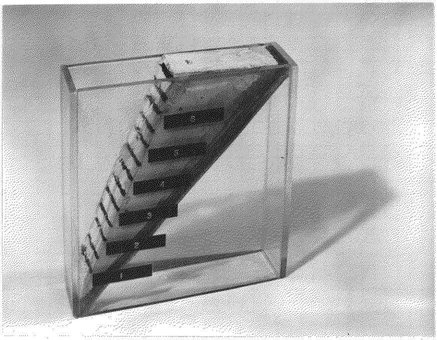

Figure 2. Modified portion of Curbell Turbidity Tester.

approximate depth of three-eighths inch. Rice kernels were placed in the cup until the top layer of the rice was just covered by the water. This method prevented the formation of air pockets which could propagate erroneous readings. Standardization of the instrument was checked before each reading. The white standard, $L = 93.1$, $a_L = -0.4$, and $b_L = +4.7$, was utilized. Readings closest to the standard were indicative of most desirable quality. Readings on the "L," "a_L," and "b_L" scales were obtained for each sample. Later investigations revealed that the "b_L" reading (yellowness) best described differences in canned rice color. Other foods which comprise a combination of colors usually require a calculation of the color difference Delta E or a ratio of "a_L" to "b_L" as in the case of tomatoes (32).

4. Subjective rating. Rice samples were grouped subjectively into seven categories relating general appearance, texture, and condition of surface (Figure 3). The rating and numerical scoring were as follows:

   a. Poor. (1.0) Mushy rice with severe end and longitudinal splitting or more than five lateral fissures.

   b. Poor plus. (1.5) Rice which does not clearly fall into either the poor or fair categories.

   c. Fair. (2.0) Slightly mushy rice with more than two lateral fissures including non-severe longitudinal fissures or split ends.

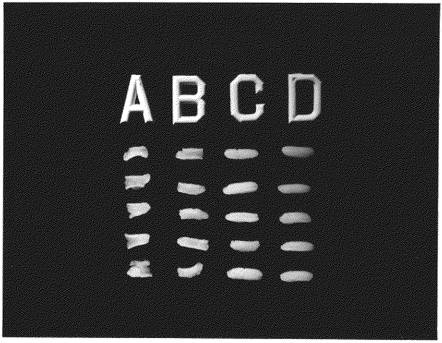

Figure 3. Subjective rating. From left to right: poor, fair, good, and excellent.

d. Fair plus. (2.5) Rice which does not clearly fall into either the fair or good categories.

e. Good. (3.0) Very slightly mushy rice with no more than two lateral fissures.

f. Good plus. (3.5) Rice which does not clearly fall into either the good or excellent categories.

g. Excellent. (4.0) Firm rice with no more than occasional cracking and no sloughing.

5. Texture. The L.E.E.-Kramer Shear Press was employed to provide objective measurements of texture and firmness of canned rice kernels. Samples of 90 grams of rice were weighed into the test cell. Each shear-compression curve was purveyed on recorder paper for later analysis.

Statistical Method

This study was designed as a complete factorial of four varieties (Jojutla, Texas Patna, Belle Patna, and Century Patna 231), five levels of parboiling (raw, 2.5, 5.0, 10.0, and 15.0 minutes), three pH's (4.5, 6.5, and 8.5), three levels of calcium lactate (0.00, 0.25, and 0.50 percent) and three blanch times (10, 15, and 20 minutes). Of primary interest were differences between varieties, treatments, and the first order interaction of these varieties and treatments (8).

To help clarify the method used for the presentation of experimental data, a short review of the linear additive model for analysis of variance and interaction terminology is in order.

An observation, as presented in elementary statistics texts (28), may be considered the sum of the population mean, the positive or negative deviation from the mean due to treatments and the effect of the random error. In formula form, the simplest model is as follows:

$$x = \mu + \tau + \epsilon \quad \text{(mu, Tau, epsilon)}$$

x = observation $\qquad$ τ = treatment condition

μ = mean $\qquad$ ϵ = random error

The tables presented throughout the text of this thesis are tables of treatment contributions (Tau's) and not actual observations. Therefore in a table of main or individual effects, a positive number means that treatment resulted in a reading higher than the average, whereas the opposite is true for a negative number.

The interaction tables give numbers which indicate the deviation from additivity of the individual treatment effects. That is, the total effect of A and B in combination is the sum of A and B and the interaction of A and B. This is perhaps best explained in the hypothetical example below.

1. Individual effects due to levels of treatment A -12, +7, +4, +1
2. Individual effects due to levels of treatment B -1, +2, +5, +6.
3. Interacting effects of A and B:

Levels of A

Levels of B		A_1	A_2	A_3	A_4
	B_1	-1	+2	+1	-2
	B_2	+6	+2	-3	-5
	B_3	-3	+5	-2	0
	B_4	-2	-9	+4	+4

These treatment effects are then presented in a combination table as follows:

Treatment		-12	+7	+4	+1
	Main effects	A_1	A_2	A_3	A_4
B_1	-1	-1	+2	+1	-2
B_2	+2	+6	+2	-3	-5
B_3	+5	-3	+5	-2	0
B_4	-6	-2	-9	+4	+7

To find the overall or total effect of level A_1 in combination with level B_1 the number appearing in the squane A_1, B_1 is added to the main effects of A_1 and B_1, that is, (-12) + (-1) + (-1) is the total effect and it is slightly less than would be expected if the individual effects were additive.

CHAPTER IV

RESULTS AND DISCUSSION

Determination of Parboiling Degree

The colorimetric and iodometric methods of Roberts et al. (27) were employed to substantiate the conclusion that the five parboiling treatments employed in this study resulted in differences in parboiling degree. These results paralleled Roberts' data with one exception. This will be discussed later.

After an initial decrease, the Gardner Color and Color Difference Meter readings indicated a general linear trend with the 15 minute steam treatment giving the darkest grain color (Table 1).

Table 1. Color Difference Meter b_L values of dry raw and parboiled rice.

Treatment	Variety			
	Texas Patna	Jojutla	C.P. 231	Belle Patna
Raw	50.1	56.0	52.5	58.7
2.5 minutes	40.0	43.4	46.1	45.8
5.0 minutes	38.4	42.0	46.3	43.5
10.0 minutes	37.2	38.5	42.3	38.7
15.0 minutes	34.4	35.7	38.2	37.6

The tomato red place, $L = 23.0$, $a_L = 24.7$, $b_L = 12.4$, was used as the standard for the color difference meter. Therefore, the smallest reading of b_L is analagous to less color difference from the standard or greater deviation from whiteness. These color data paralleled the results of Roberts et al. (27) in that within a given variety and process, the color of the grain can be used as an index of parboiling degree. To further confirm the differences in parboiling treatment, the iodine blue test was performed on the 20 samples of raw and parboiled rice (Table 2).

Table 2. Iodine percent transmission values of raw and parboiled rice.

Treatment	Variety			
	Texas Patna	Jojutla	C.P. 231	Belle Patna
Raw	96	96	96	96
2.5 minutes	74	81	88	70
5.0 minutes	60	79	82	64
10.0 minutes	54	79	75	60
15.0 minutes	63	81	81	70

Roberts et al. (27) theorized that the more severely parboiled rice would contain a higher soluble starch fraction because of granule breakdown. Data collected during this study substantiated the theory through the 10 minute treatment, but the 15 minute steam treatment resulted in a smaller soluble starch fraction for all the varieties tested. It is not possible at the present time to make a determinative postulation as to why this phenomenon occurred. Roberts et al. (27) found the soluble starch determination to be more erratic than the colorimetric method; it is possible that the soluble starch values for the 15 minute treatment were lower because of inherent discrepancies in the method. However, because of the consistency of this trend, it would be easy to postulate a different course of reaction. Studies including longer steam times would be warranted.

Another interesting observation resulting from the iodine determination was the similarity of iodine values between varieties with greatly different natural amylose contents. For example, Jojutla, a variety with over 30 percent amylose produced iodine values very close to Century Patna 231 which has an amylose content of 15 percent (29). One would expect varieties with a higher natural soluble amylose fraction to carry through with a higher soluble fraction when parboiled. Belle Patna and Texas Patna behaved in this general manner, but because Jojutla did not, no general conclusion may be drawn.

Results and Discussion of Analyses

The main objective of this study was to evaluate the effect and interaction of varieties and processing variables upon canned rice quality. The processing variables were parboiling, pH, calcium lactate, and blanch time. Data collected included drained weight, turbidity readings, color difference values, shear press readings, and subjective ratings.

It was necessary to utilize the technique of least squares in the analysis of variance because 34 of 540 cans of rice were lost to bacterial spoilage. Each quality criterion was analyzed separately. The six analyses were reported individually; the combined results were considered in the final formulation of an optimum process for canned rice.

Analysis I: Drained weight - Drained weight data can be misleading if the results are not carefully interpreted. For example, decreased water uptake which is desirable and kernel disintegration which is undesirable can both result in similar low drained weight readings. The analysis of variance is presented in Table 3.

Table 3. Analysis of variance - drained weight.

Source	Degrees of freedom	Mean square	F
Total	505	136.51	3.42**
Variety	3	4558.96	114.53**
Parboil	4	1289.44	32.39**
pH	2	5165.19	129.76
Calcium lactate	2	1365.84	34.31**
Blanch	2	301.37	7.57**
Variety × parboil	12	263.80	6.62**
Variety × pH	6	712.31	17.89**
Variety × calcium lactate	6	288.57	7.24**
Variety × blanch	6	85.83	2.15*
Parboil × pH	8	36.21	0.91N.S.
Parboil × calcium lactate	8	40.00	1.00N.S.
Parboil × blanch	8	57.25	1.44N.S.
pH × calcium lactate	4	1580.09	39.70**
pH × blanch	4	27.36	0.69N.S.
Calcium lactate × blanch	4	37.51	0.94N.S.
Residual	426	39.80	----

The response scale for each significant main effect and interaction is presented and interpreted as follows:

1. Varieties - Drained weight differences between varieties was highly significant as shown in Table 4.

Table 4. Drained weight response to varietal differences.

Variety :	Texas Patna	Jojutla	C.P. 231	Belle Patna
Response :	1.53	-9.34	3.93	3.88

Jojutla consistently resulted in the lowest drained weight, Texas Patna was intermediate, and Century Patna 231 and Belle Patna gave similar high readings. These weight differences are attributed to inherent characteristics which influence the water uptake capacity of various rice varieties as was illustrated by Dawson et al. (4).

2. Parboiling - The parboiling treatments resulted in a steady gradient on the response scale as indicated in Table 5.

Table 5. Drained weight response to parboiling treatments.

Parboiling :	Raw	2.5 Min.	5 Min.	10 Min.	15 Min.
Response :	4.05	1.94	1.39	-2.55	-4.83

Raw rice had the highest drained weight and the 15 minute steam treatment resulted in the lowest drained weight. The mechanism by which parboiling toughens the grain is not completely understood. Complete gelatinization of starches would be expected at steaming times of 10 and 15 minutes. An explanation of increased stability as a result of steam treatments longer than that which is necessary for complete gelatinization cannot be theorized from the information at hand. Gelatinization at 2.5 and 5.0 minutes may not have been complete as ungelatinized hard centers were generally noticeable at these shorter steaming times.

3. pH - The treatment at pH 4.5 resulted in a low drained weight, and pH 6.5 and 8.5 gave higher but virtually similar responses (Table 6).

Table 6. Drained weight response to pH differences.

pH	:	4.5	6.5	8.5
Response	:	-6.38	3.26	3.12

The response of pH 4.5 is attributed to the substantial amount of acid required to reduce calcium lactate solutions to that pH. In fact, acid hydrolysis is the logical explanation for reduced weight at pH 4.5. This will be discussed further in the section on the interaction between pH and calcium lactate.

4. Calcium lactate - The response scale for calcium lactate treatments is presented in Table 7.

Table 7. Drained weight response to calcium lactate treatments.

Calcium lactate	:	Distilled water	0.25%	0.50%
Response	:	3.25	-1.24	-2.01

For the reason mentioned above and the possibility that calcium lactate causes sloughing of grain material as does magnesium sulfate (9), the calcium lactate treatment resulted in high drained weights at the zero level and lower readings at 0.25 percent and 0.50 percent, respectively.

5. Blanch time - The main effect of increased blanch time was to reduce the drained weight of the sample (Table 8).

Table 8. Drained weight response to blanch time differences.

Blanch time :	10 Min.	15 Min.	20 Min.
Response :	0.80	0.77	-1.57

The results of the 10 and 15 minute treatments were similar; the 20 minute treatment resulted in substantially lower drained weights. The reaction to the 20 minute blanch may be logically explained as sloughing due to overprocessing.

6. Variety x parboil - The reaction of varieties to various parboiling treatments is presented in Table 9.

Table 9. Drained weight response to variety x parboil interaction.

Treat-ment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
Parboil	Main effects	1.53	-9.34	3.93	3.88
			Interaction		
Raw	4.05	-5.06	0.36	5.16	-0.46
2.5 Min.	1.94	0.27	-1.88	0.68	0.93
5.0 Min.	1.39	0.43	-0.75	2.37	-2.05
10.0 Min.	-2.55	2.21	1.76	-5.52	3.60
15.0 Min.	-4.83	2.15	0.51	-2.69	0.03

This first order interaction was highly significant. The extreme variability of interaction response can be attributed to varietal characteristics. It may be stated that the varieties of this study responded to the parboiling treatment in different ways as far as drained weight was concerned. This action was not unexpected. Varietal differences in response to parboiling treatments have long been recognized (17, 29).

7. Variety x pH - The total effect of pH on all varieties was a lower drained weight at pH 4.5 than at 6.5 or 8.5. The interactions indicated in Table 10, however, show different reactions between varieties.

Table 10. Drained weight response to variety x pH interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
pH	Main effects	1.53	-9.34	3.93	3.88
		Interaction			
4.5	-6.38	2.53	4.52	-6.27	-0.78
6.5	3.26	-1.37	-1.33	3.25	-0.55
8.5	3.12	-1.16	-3.19	3.02	1.33

Texas Patna and Jojutla interacted with pH with a tendency for a higher drained weight at pH 4.5 than 6.5 or 8.5. Belle Patna showed a slight upward response, while Century Patna 231 interacted with a tendency for lower drained weights at pH 4.5 and higher readings at pH 6.5 and 8.5.

8. Variety x calcium lactate - The calcium lactate resulted in high drained weights at the zero level and lower drained weights at the 0.25 percent and 0.50 percent levels (Table 11).

Table 11. Drained weight response to variety x calcium lactate interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
Calcium lactate	Main effect	1.53	-9.34	3.93	3.88
		Interaction			
0.00	3.25	-1.67	-2.60	3.99	0.28
0.25%	-1.24	0.42	0.70	-1.01	-0.11
0.50%	-2.01	1.25	1.90	-2.98	-0.17

The interaction showed an upward trend for Texas Patna and Jojutla, a slightly downward trend for Belle Patna and a sharply decreasing tendency for Century Patna 231.

9. Variety x blanch - The interaction between varieties and blanch time was significant at the five percent level. As indicated in Table 12, the total effect was a gradual downward trend in drained weights with increased blanch times. The exception to this was Texas Patna, which showed higher drained weights with longer blanch times.

Table 12. Drained weight response to variety x blanch time interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
Blanch	Main effect	1.53	-9.34	3.93	3.88
		Interaction			
10 Min.	0.80	-0.92	-0.05	1.27	-0.30
15 Min.	0.77	-0.89	-0.37	0.74	0.52
20 Min.	-1.57	1.81	0.42	-2.01	-0.22

The interaction table shows increasing trends for Texas Patna and Jojutla. Century Patna 231 and Belle Patna interact to give lower values with increased blanch time. The interaction with Texas Patna was strong enough to overrule the main effect and result in the only total effect which showed a higher drained weight with the 20 minute blanch than with the 10 or 15 minute treatments.

10. pH x calcium lactate - The interaction of pH with calcium lactate as shown in Table 13 had one of the most pronounced effects of all the variables on the drained weight of canned rice.

Table 13. Drained weight response to pH x calcium lactate interaction.

Treatment	pH	4.5	6.5	8.5
Calcium lactate	Main effect	-6.38	3.26	3.12
		Interaction		
0.00	3.25	6.78	-3.64	-3.14
0.25%	-1.24	-1.86	1.08	0.78
0.50%	-2.01	-4.92	2.56	2.36

The total effect for pH 6.5 and 8.5 was a slight increase in drained weights with the addition of calcium lactate to the fill solutions. At pH 4.5, the zero level of calcium lactate produced the highest drained weight, but the addition of sufficient acid to bring the pH of the 0.25 percent and 0.50 percent calcium lactate solutions to 4.5 resulted in acid hydrolysis of starches and extremely low drained weights.

Analysis II: Turbidity of undisturbed fill liquid - These turbidity measurements were made on the undisturbed fill liquid. Therefore, the resultant turbidity was due to the influence of color and any suspended or dissolved material from the rice grain. Sloughed particles large enough to settle were not a factor in this measurement. The analysis of variance is presented in Table 14.

Table 14. Analysis of variance - turbidity of undisturbed fill liquid.

Source	Degrees of freedom	Mean square	F
Total	505	3.36	3.46**
Variety	3	137.57	141.55**
Parboil	4	31.53	32.44**
pH	2	199.16	204.93**
Calcium lactate	2	49.01	50.44**
Blanch	2	5.13	5.28**
Variety × parboil	12	4.45	4.58**
Variety × pH	6	2.51	2.58*
Variety × calcium lactate	6	4.20	4.32**
Variety × blanch	6	1.81	1.86N.S.
Parboil × pH	8	1.78	1.83N.S.
Parboil × calcium lactate	8	2.82	2.89**
Parboil × blanch	8	0.54	0.56N.S.
pH × calcium lactate	4	27.44	28.23**
pH × blanch	4	0.27	0.28N.S.
Calcium lactate × blanch	4	0.09	0.09N.S.
Residual	426	0.97	----

Response scale tables for each significant main effect and interaction in Table 14 are presented and interpreted as follows:

1. Varieties - The Curbell Turbidity Tester is arranged so that less turbid liquids give higher turbidity numbers. That is, a liquid

with a turbidity number of eight would be clearer than a liquid with a turbidity number of 2. In Table 15, according to ascending order of turbidity, the varieties of this study ranked (1) Jojutla, (2) Texas Patna, (3) Belle Patna, and (4) Century Patna 231.

Table 15. Turbidity response of undisturbed fill liquid to varietal differences.

Variety :	Texas Patna	Jojutla	C.P. 231	Belle Patna
Response :	0.12	1.22	-1.39	0.05

Century Patna 231 kernels were often disrupted so completely that absorbed water rendered the whole can contents a congealed pasty mass. Broth samples of Texas Patna and especially Jojutla were usually so clear that the range of the turbidity tester was extended to its maximum.

2. Parboiling - It is logical to assume from prior knowledge of the behavior of parboiled rice that the more severely parboiled samples would result in a more stable canned product with less turbidity of the canning liquid. Such was the case in this instance as may be seen in Table 16.

Table 16. Turbidity response of undisturbed fill liquid to parboiling treatments.

Parboiling :	Raw	2.5 Min.	5 Min.	10 Min.	15 Min.
Response :	-0.98	0.23	0.05	0.31	0.39

Raw rice resulted in greater turbidity; the 15 minute parboiling treatment exhibited the least turbid liquid. The one exception to the decrease in turbidity with the increase in parboiling time was the reversal of the 2.5 and 5 minute treatments. However, the turbidity of the fill liquid for the four parboiled samples was indeed so close that it would be impossible to say that this reversal of trend was not a chance occurrence.

3. pH - As was the case with the drained weight data, the low pH of 4.5 again resulted in the least desirable product (Table 17).

Table 17. Turbidity response of undisturbed fill liquid to pH differences.

pH	:	4.5	6.5	8.5
Response	:	-1.25	0.65	0.61

The degradation by acid which led to low drained weights also produced very turbid solutions. The pH's of 6.5 and 8.5 produced similar readings with the former being slightly better.

4. Calcium lactate - As may be seen in Table 18, the addition of calcium lactate to the fill water resulted in an increase in the turbidity of the canning liquor.

Table 18. Turbidity response of undisturbed fill liquid to calcium lactate treatments.

Calcium lactate	:	0.00	0.25%	0.50%
Response	:	0.61	-0.17	-0.44

This reaction is again attributable at least partially to the effect of the excess acid at pH 4.5. It is also probable that the calcium lactate affected a sloughing action on surface particles of the rice grain since the turbidity of the higher pH solutions went up with the addition of calcium lactate.

5. Blanch time - The main effects of the blanch time on turbidity (Table 19) resulted in a peak at the intermediate time of 15 minutes and greater turbidities at the 10 and 20 minute treatments.

Table 19. Turbidity response of undisturbed fill liquid to blanch time differences.

Blanch time	:	10 Min.	15 Min.	20 Min.
Response	:	-0.04	0.19	-0.15

Two factors at work are the leaching and cooking effects of the blanch treatment. If the blanch time is too short, the remaining leachable materials will create turbidity of the broth. On the other hand, if the blanch is too long, over processing can occur with resultant breakdown and increased turbidity. The two extremes may well be exemplified by the results of this analysis which shows the lowest turbidity reading at the intermediate level.

6. Variety x parboil - As indicated in Table 20, the interactions of variety and parboil produced complex or confounded effects.

Table 20. Turbidity response of undisturbed fill liquid to variety x parboil interaction.

Treat-ment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
Parboil	Main effect	0.12	1.22	-1.39	0.05
		Interaction			
Raw	-0.98	-0.15	-0.18	0.49	-0.16
2.5 Min.	0.23	-0.52	0.00	-0.11	0.63
5.0 Min.	0.05	0.27	-0.23	0.09	-0.13
10.0 Min.	0.31	-0.06	0.65	-0.17	-0.43
15.0 Min	0.39	0.46	-0.24	-0.30	0.08

The main and total effect was for decreased turbidity with increasing parboil treatment, but the interaction trends are inconsistent and unexplainable at the present time. For instance, Jojutla shows a high reading at the 10 minute parboil treatment and a lower reading at the 15 minute treatment than the raw sample exhibited. In fact, because of this strong interaction at the 15 minute treatment, the total effect for Jojutla shows an increased turbidity between the 10 and 15 minute treatment. All other varieties showed increases in clarity of broth through the highest degree of parboiling.

7. Variety x pH - Century Patna 231 and Belle Patna exhibited interaction trends with the same general trend as the total effects (Table 21).

Table 21. Turbidity response of undisturbed fill liquid to variety x pH interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
pH	Main effect	0.12	1.22	-1.39	0.05
		Interaction			
4.5	-1.25	0.12	0.03	0.11	-0.26
6.5	0.65	-0.05	-0.30	0.11	0.24
8.5	0.61	-0.07	0.27	-0.22	0.02

The broth turbidity decreased at the central pH 6.5 and increased again at pH 8.5. Texas Patna responded with a straight increase in turbidity from pH 4.5 through pH 8.5. The interaction line of Jojutla started with a medium level of turbidity at pH 4.5, increased rapidly at pH 6.5 to the most turbid point and then decreased to pH 8.5 with a less turbid solution than those samples at pH 4.5 or 6.5.

8. Variety x calcium lactate - The total effect for all varieties was a gradual increase in turbidity with added increments of calcium lactate as may be seen in Table 22.

Table 22. Turbidity response of undisturbed fill liquid to variety x calcium lactate interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
Calcium lactate	Main effect	0.12	1.22	-1.39	0.05
		Interaction			
0.00	0.61	0.43	-0.39	-0.17	0.13
0.25%	-0.17	-0.14	0.25	0.02	-0.13
0.50%	-0.44	-0.29	0.14	0.15	0.00

The interaction table again shows very different reactions between varieties. Texas Patna and Belle Patna tended to produce more turbid liquids with the addition of calcium lactate. Jojutla's and Century Patna's interaction with calcium salt would tend to produce less turbid readings with the added salt.

9. Parboil x calcium lactate - As indicated in Table 23, the total effect for all parboiling treatments was increased turbidity with the addition of calcium lactate to the fill liquid.

Table 23. Turbidity response of undisturbed fill liquid to parboil x calcium lactate interaction.

Treatment	Parboil	Raw	2.5	5 Min.	10 Min.	15 Min.
Calcium lactate	Main effect	-0.99	0.23	0.05	0.31	0.40
		Interaction				
0.00	0.16	0.34	0.21	0.05	-0.19	-0.41
0.25%	-0.17	-0.24	0.09	-0.04	0.14	0.05
0.50%	-0 44	-0.10	-0.30	-0.10	-0.05	0.36

The interaction of parboiling treatments, raw, 2.5 minutes and 5 minutes with calcium lactate, tended to produce more turbid liquids. Parboilings of 10 and 15 minutes exhibited tendencies to become less turbid with added calcium lactate.

10. pH x calcium lactate - The total effect for all pH treatments was a trend for increasing turbidities with the addition of calcium salt (Table 24).

Table 24. Turbidity response of undisturbed fill liquid to pH × calcium lactate interaction.

Treatment	pH	4.5	6.5	8.5
	Main effect	-1.25	0.65	0.60
Calcium lactate			Interaction	
0.00	0.60	0.89	-0.57	-0.32
0.25%	-0.17	-0.32	0.14	0.18
0.50%	-0.43	-0.57	0.43	0.14

The table for total effects and interaction for this analysis is very similar to the one for drained weight. This is to be expected in that turbidity and drained weight are similarly related. The pH 4.5 and 0.25 percent or 0.50 percent calcium lactate treatment produced the more turbid liquids. The total effect at pH 6.5 and 8.5 was a slight decrease with added salt, but the interaction was opposite in that the higher pH liquids were more turbid without calcium lactate.

Analysis III: Turbidity of the agitated fill liquid - The turbidity measurements in this analysis were made to relate conditions which resulted in the sloughing of material from the rice grain. The turbidity of the agitated liquid was a combination of the dissolved fraction and suspended materials. The analysis of variance is shown in Table 25.

Table 25. Analysis of variance - turbidity of agitated fill liquid.

Source	Degrees of freedom	Mean square	F
Total	505	1.75	2.96**
Variety	3	79.91	135.06**
Parboil	4	4.17	7.06**
pH	2	11.60	19.61**
Calcium lactate	2	112.76	190.58**
Blanch	2	6.00	10.14**
Variety × parboil	12	3 33	5.62**
Variety × pH	6	1.16	1.97N.S.
Variety × calcium lactate	6	1.19	2.00N.S.
Variety × blanch	6	0.53	0.89N.S.
Parboil × pH	8	1.32	2.24*
Parboil × calcium lactate	8	0.25	0.43N.S.
Parboil × blanch	8	0.70	1.19N.S.
pH × calcium lactate	4	1.36	2.30*
pH × blanch	4	0.51	0.86N.S.
Calcium lactate × blanch	4	2.36	4.00**
Residual	426	0.59	----

Response scale tables for each significant main effect and interaction in Table 25 are presented and interpreted as follows:

1. Varieties - As shown in Table 26, the four varieties of this study held the same relative position for the agitated broth turbidity analysis as they had shown in the previous turbidity analysis.

Table 26. Turbidity response of agitated fill liquid to varietal differences.

Variety :	Texas Patna	Jojutla	C.P. 231	Belle Patna
Response :	0.59	0.75	-0.92	-0.42

The Jojutla broth was the least turbid, Texas Patna was second, Belle Patna was third and the liquor of Century Patna 231 was the most turbid.

2. Parboiling - Table 27 reveals a reversal of form from the previous turbidity analysis.

Table 27. Turbidity response of agitated fill liquid to parboiling treatments.

Parboiling :	Raw	2.5 Min.	5 Min.	10 Min.	15 Min.
Response :	0.22	0.20	-0.24	-0.10	-0.08

The turbidity response table for parboiling indicates that the raw and very slightly parboiled rice produced less sloughed grain material than did the heavily parboiled samples. Parboiling toughens the grain (17). It would, therefore, be logical to assume that the more severely parboiled samples would result in less sloughed materials. However, since the opposite is true, one speculative explanation of consequence would be that there is minute checking of the parboiled rice surface during the drying process. Such surface checking could subsequently result in sloughing of grain material during the sterilization process. Another source of sloughed material could be the ruptured kernels which are produced in the parboiling process. As steaming times are increased, the number of ruptured kernels during parboiling generally increases. In extreme cases, this rupturing is severe and might also contribute to increased turbidity of the agitated fill liquid (29).

3. pH - The acid hydrolysis at pH 4.5, which resulted in turbid undisturbed solutions, acted to rid the can of sloughed particles and resulted in the least turbid of agitated fill liquids. The turbidity of solutions at pH 6 5 and 8.5 were quite similar (Table 28).

Table 28. Turbidity response of agitated fill liquid to pH differences.

pH	:	4.5	6.5	8.5
Response	:	0.30	-0.16	-0.14

4. Calcium lactate - Once again, the sloughing action of calcium lactate at all pH's and especially at pH 4.5 produced agitated liquids with greater turbidities than did the zero treatment. The difference in turbidity between 0.25 percent and 0.50 percent calcium lactate treatments are negligible (Table 29).

Table 29. Turbidity response of agitated fill liquid to calcium lactate treatments.

Calcium salt	:	0.00%	0.25%	0.50%
Response	:	0.94	-0.46	-0.48

5. Blanch time - As can be seen in Table 30, the intermediate blanch time of 15 minutes resulted in the least turbid agitated solution.

Table 30. Turbidity response of agitated fill liquid to blanch time differences.

Blanch time	:	10 Min.	15 Min.	20 Min.
Response	:	-0.17	0.20	-0.03

Since the turbidity reading for the agitated solution was the result of the combination of sloughed and dissolved materials, it is reasonable to assume that the turbidity of the 10 minute blanch was due to leachable materials from the grain. It is also probable that the increased turbidity of the 20 minute treatment was the result of sloughed grain material due to over processing.

6. Variety x parboil - The total effect for all varieties was a slight increase in turbidity with the longer parboiling steam times (Table 31).

Table 31. Turbidity response of agitated fill liquid to variety x parboil interaction.

Treat-ment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
Parboil	Main effect	0.59	0.75	-0.92	-0.42
		Interaction			
Raw	0.22	0.17	-0.57	0.36	0.04
2.5 Min.	0.20	-0.12	-0.32	0.10	0.34
5.0 Min.	-0.24	-0.06	0.12	0.01	-0.19
10.0 Min.	-0.10	-0.11	0.74	-0.22	-0.41
15.0 Min.	-0.08	0.00	0.03	-0.25	0.22

The same general trend is shown for interaction effects. An exception is the interaction trend of Jojutla which again decreases in turbidity rapidly at the 10 minute treatment, but reverses and becomes more turbid at the 15 minute parboil time.

7. Parboil x pH - As indicated in Table 32, the total effect for all parboiling treatments was more turbid liquids at pH 6.5 and 8.5 and less turbidity at pH 4.5.

Table 32. Turbidity response of agitated fill liquid to parboil x pH interaction.

Treatment	Parboil	Raw	2.5 Min.	5 Min.	10 Min.	15 Min.
	Main effect	0.22	0.20	-0.24	-0.10	-0.08
pH		Interaction				
4.5	0.30	-0.12	0.14	0.31	-0.09	-0.24
6.5	-0.16	0.09	0.00	-0.18	-0.01	0.10
8.5	-0.14	0.03	-0.14	-0.13	0.10	0.14

This action may be explained as acid hydrolysis which alleviated the accumulation of sloughed particles at the lowest pH. The response table shows diverse trends of interaction for the five parboiling treatments. For the raw, 10 minute and 15 minute treatments, the trend is toward less turbid solutions with rising pH. The 2.5 and 5.0 minute treatments exhibit trends for increased turbidity of the agitated fill with an increase in pH.

8. pH x calcium lactate - The total effect for each pH was more turbidity at the 0.25 percent and 0.50 percent levels of calcium lactate than at the zero level (Table 33).

Table 33. Turbidity response of agitated fill liquid to pH × calcium lactate interaction.

Treatment	pH	4.5	6.5	8.5
	Main effect	0.30	-0.16	-0.14
Calcium lactate		Interaction		
0.00	0.94	-0.20	-0.10	0.10
0.25%	-0.46	0.08	0.06	-0.14
0.50%	-0.48	0.12	-0.16	0.14

The interaction trend for pH 4.5 was a decrease in turbidity with the addition of calcium salt. Once again, the presence of surplus acid at pH 4.5 could account for the upward interaction trend and lack of sloughed grain material.

9. Calcium lactate × blanch - As can be seen in Table 34, the zero calcium treatment showed an interaction trend which decreased in turbidity from the 10 minute to the 15 minute blanch, but then sharply became more turbid at the 20 minute treatment.

Table 34. Turbidity response of agitated fill liquid to calcium lactate × blanch time interaction.

Treatment	Calcium lactate	0.00	0.25%	0.50%
	Main effect	0.94	-0.46	-0.48
Blanch		Interaction		
10 Min.	-0.17	0.06	-0.04	-0.02
15 Min.	0.20	0.20	-0.04	-0.16
20 Min.	-0.03	-0.26	0.08	0.18

The trend of 0.50 percent calcium lactate solutions was opposite in that turbidity increased at the 15 minute blanch and then became less turbid at the 20 minute treatment. The turbidity of the 0.25 percent calcium lactate fill solution showed slight decreases in turbidity with the increase in blanch time from 10 minutes to 15 and 20 minutes. In total effect the zero calcium level was by far the least turbid for all blanch times.

Analysis IV: Subjective rating - The subjective ratings of this analysis were designed to provide information concerning the surface appearance of the canned rice grain. Sloughing, splitting, cracking, and general surface appearance were taken into account in the awarding of a particular rating. Unfortunately, most varieties were so obviously within one range that little differentiation between treatments was discernable. Analysis of variance results are shown in Table 35.

Table 35. Analysis of variance - subjective rating.

Source	Degrees of freedom	Mean square	F
Total	505	0.74	17.62**
Variety	3	62.22	1480.11**
Parboil	4	26.69	634.87**
pH	2	0.04	1.04N.S.
Calcium lactate	2	0.11	2.54N.S.
Blanch	2	0.20	4.78**
Variety × parboil	12	4.47	106.24**
Variety × pH	6	0.07	1.66N.S.
Variety × calcium lactate	6	0.07	17.57**
Variety × blanch	6	0.09	2 37**
Parboil × pH	8	0.09	2.32**
Parboil × calcium lactate	8	0.10	2.42**
Parboil × blanch	8	0.05	1.12N.S.
pH × calcium lactate	4	0.17	3.98**
pH × blanch	4	0.03	0.73N.S.
Calcium lactate × blanch	4	0.04	0.85N.S.
Residual	426	0.04	----

Response scale tables for each significant main effect and interaction in Table 35 are presented and interpreted as follows:

1. Varieties - Jojutla, Texas Patna, Belle Patna, and Century Patna 231 in that order presented the most to least attractive canned rice products (Table 36).

Table 36. Subjective rating response to varietal differences.

Variety :	Texas Patna	Jojutla	C.P. 231	Belle Patna
Response :	0.18	0.84	-0.89	-0.13

Century Patna 231 was so unsuited for this type formulation that it was graded poor in all instances. It was possible, however, to discern certain treatment differences within the other varieties of this study.

2. Parboiling - As should be expected, the appearance of the canned rice improved with the more severe parboiling treatments (Table 37).

Table 37. Subjective rating response to parboiling treatments.

Parboiling	:	Raw	2.5 Min.	5 Min.	10 Min.	15 Min.
Response	:	-0.90	0.12	0.07	0.27	0.44

It is not known why the 15 minute treatment is better than the 10 minute treatment when complete gelatinization most likely occurs near the 5 minute treatment. It is possible that there are other factors besides gelatinization affecting the toughening of the grain that have not gone to completion at the lower treatments. It would be interesting academically to pursue the parboiling treatments to extreme limits of time and temperature.

3. Blanch time - Once again as indicated in Table 38, the medium treatment of 15 minutes resulted in the best appearing canned rice.

Table 38. Subjective rating response to blanch time.

Blanch time	:	10 Min.	15 Min.	20 Min.
Response	:	-0.04	0.03	0.01

The 10 minute blanch time in this analysis and lower blanch times in preliminary work indicated that the sudden increase in hydration during the retorting process caused the rice kernels to disrupt more than would be expected. It appears as though approximately 15 minutes is the medium blanch time where the disrupting action of sudden hydration and of over-processing which may occur with longer blanch times is held to a minimum.

4. Variety x parboil - In total effect each variety except Century Patna 231 reacted to the parboiling treatments to produce an improved appearance (Table 39).

Table 39. Subjective rating response to variety x parboil interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
Parboil	Main effect	0.18	0.84	-0.89	-0.13
		Interaction			
Raw	-0.90	-0.18	-0.85	-0.89	-0.14
2.5 Min.	0.12	-0.26	0.27	-0.12	0.11
5.0 Min.	0.07	0.13	0.15	-0.07	-0.21
10.0 Min.	0.27	0.12	0.19	-0.26	-0.05
15.0 Min.	0.44	0.19	0.24	-0.44	0.01

Century Patna 231 responded to parboiling to a small degree. It never rated better than poor, but the raw and slightly parboiled samples were noticeably worse than those with longer treatments.

5. Variety x calcium lactate - The interaction of varieties and calcium lactate was significant, but the interaction was so small when compared to the main effects as to be of no real consequence. Each variety exhibited slightly downward trends in rating with the addition of calcium salt. Belle Patna went down and back up, but never achieved the rating of the zero level of calcium lactate (Table 40).

Table 40. Subjective rating response to variety x calcium lactate interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
Calcium lactate	Main effect	0.18	0.84	-0.89	-0.13
		Interaction			
0.00	0.02	0.04	-0.02	-0.02	0.00
0.25%	0.01	-0.03	-0.02	-0.01	0.06
0.50%	-0.03	-0.01	0.04	0.03	-0.06

6. Variety x blanch - Once again, the interaction had little effect on the total response (Table 41).

Table 41. Subjective rating response to variety x blanch time interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
Blanch	Main effect	0.18	0.84	-0.89	-0.13
		Interaction			
10 Min.	-0.04	-0.06	0.01	0.03	0.02
15 Min.	0.03	0.07	0.00	-0.03	-0.04
20 Min.	0.01	-0.01	-0.01	0.00	0.02

This interaction was significant mainly because of the great varietal differences. Although in total effect the rice showed virtually no response in appearance to the blanch treatments. The tendency, however, was for all varieties to exhibit the best appearance at the 15 minute blanch time.

7. Parboil x pH - As can be seen in Table 42, the total effect was little or no response among parboiling treatments to increases in the pH.

Table 42. Subjective rating response to parboil x pH interaction.

Treat-ment	Parboil	Raw	2.5 Min.	5 Min.	10 Min.	15 Min.
pH	Main effect	-0.89	0.12	0.07	0.27	0.43
				Interaction		
4.5	-0.02	0.02	-0.02	0.07	0.01	-0.08
6.5	0.00	0.00	0.00	0.00	0.01	-0.01
8.5	0.02	-0.02	0.02	-0.07	-0.02	0.09

The general trend was toward slightly better appearance as the pH rose from 4.5 to 8.5. An unexplainably strong interaction for decreased rating at the 5.0 minute parboiling level was influential enough so that the total effect for the 5.0 minute treatment was a decrease in rating with an increase in the pH scale.

8. Parboil x calcium lactate - The interactions between parboiling and calcium lactate were not sufficiently strong to induce a pronounced effect on the total response. As shown in Table 43, the total effect trend was for large differences between parboiling,

but little response to added increments of calcium salt.

Table 43. Subjective rating response to parboil x calcium lactate interaction.

Treatment	Parboil	Raw	2.5 Min.	5 Min.	10 Min.	15 Min.
Calcium lactate	Main effect	-0.89	0.12	0.07	0.27	0.43
		Interaction				
0.00	0.02	-0.02	0.05	0.03	-0.02	-0.04
0.25%	0.01	-0 01	-0.02	0.05	0.02	-0.04
0.50%	-0.03	0.03	-0.03	-0.08	0.00	0.08

9. pH x calcium lactate - At the zero level of calcium lactate, the pH 4.5 treatment resulted in the best rating. The pH of 6.5 produced best results at the 0.25 percent level of calcium salt. Similarly, pH 8.5 gave best results at the highest calcium level, 0.50 percent (Table 44).

Table 44. Subjective rating response to pH x calcium lactate interaction.

Treatment	pH	4.5	6.5	8.5
Calcium lactate	Main effect	-0.02	0.00	0.02
		Interaction		
0.00	0.02	0.06	-0.04	-0.02
0.25%	0.01	-0.02	0.04	-0.02
0.50%	-0.03	-0.04	0.00	0.04

Analysis V: Canned rice color - Color measurements, using the Gardner Color and Color Difference Meter, were made on drained rice kernels to which clear water had been added to prevent the formation of air pockets. Since whiteness of grain is preferred, these color comparisons with a white standard related the acceptability of a given variety or processing treatment in terms of grain color. Analysis of variance results are shown in Table 45.

Table 45. Analysis of variance - canned rice color.

Source	Degrees of freedom	Mean square	F
Total	505	3.51	4.51**
Variety	3	48.66	62.57**
Parboil	4	177.93	228.77**
pH	2	70.05	90.06**
Calcium lactate	2	56.64	72.83**
Blanch	2	6.76	8.69**
Variety × parboil	12	10.86	13.97**
Variety × pH	6	10.44	13.42**
Variety × calcium lactate	6	0.84	1.09N.S.
Variety × blanch	6	1.31	1.69N.S.
Parboil × pH	8	0.70	0.89N.S.
Parboil × calcium lactate	8	2.43	3.12**
Parboil × blanch	8	0.65	0.83N.S.
pH × calcium lactate	4	13.60	17.48**
pH × blanch	4	0.33	0.42N.S.
Calcium lactate × blanch	4	4.35	5.60**
Residual	426	0.78	----

Response scale tables for each significant main effect and interaction in Table 45 are present and interpreted as follows:

1. Varieties - As shown in Table 46, the results of this analysis indicated that on the average Texas Patna is the whitest rice.

Table 46. Canned rice color response to varietal differences.

Variety :	Texas Patna	Jojutla	C.P. 231	Belle Patna
Response :	-0.52	0.87	-0.10	-0.45

Belle Patna is next in whiteness, Century Patna 231 is third and Jojutla deviates from white the furthest. These differences will be discussed in the variety x parboiling section.

2. Parboiling - The parboiling treatments resulted in a steady color gradient from near white with raw rice to the darkest color at the 15 minute parboiling treatment (Table 47).

Table 47. Canned rice color response to parboiling treatments.

Parboiling :	Raw	2.5 Min.	5 Min.	10 Min.	15 Min.
Response :	-1.66	-0.71	-0.34	1.05	1.66

This effect was wholly expected since the browning action of the parboiling process depends primarily on the quantity of leachable materials from the hull, bran and germ which is absorbed by the rice endosperm.

3. pH - As indicated in Table 48, the main effect of the three pH treatments on rice color was the production of the most nearly white

samples at pH 6.5. Acid degradation may have been the cause of increased brownness at pH 4.5, while the alkaline browning reaction had just begun to become evident at pH 8.5 (26).

Table 48. Canned rice color response to pH differences.

pH	:	4.5	6.5	8.5
Response	:	0.73	-0.48	-0.25

4. Calcium lactate - The addition of calcium lactate to the fill liquid resulted in an increase in color of the rice grains (Table 49).

Table 49. Canned rice color response to calcium lactate treatments.

Calcium lactate	:	0.00	0.25%	0.50%
Response	:	-0.66	0.26	0.40

Reasons for this action are not readily apparent, except that the sloughing action of the salt may have resulted in concurrent color changes.

5. Blanch time - The color at the 10 minute treatment and the subsequent decrease in color at the 15 minute treatment may be attributed to the absence of leachable materials in the rice at the lower treatment which were subsequently removed during the 15 minute blanch. The substantially higher color reading at the 20 minute treatment may once again be linked with sloughing and degradation as a result of over-processing (Table 50).

Table 50. Canned rice color response to blanch time differences.

Blanch time :	10 Min.	15 Min.	20 Min.
Response :	-0.04	-0.18	0.22

6. Variety x parboil - A large part of the interaction between variety and parboil can be attributed to the color of the hull and the original color of the raw milled endosperm. For instance, Jojutla and Texas Patna which have dark hulls interact with increased parboiling times with tendencies to become darker in color. Century Patna 231 with gold hulls and Belle Patna with straw colored hulls interact negatively with the increase in parboiling time to produce in total effect canned rice with less than expected color increases with increased parboiling times.

The total effect (Table 51) is interesting in that Jojutla is definitely the whitest canned raw rice, but quickly becomes the darkest with the application of parboiling treatments. This may be due to its chalky appearance compared with the others which are usually more translucent. Canned Texas Patna was the lightest at the 2.5 and 5.0 minute treatments, but became second in darkness only to Jojutla at the 15 minute parboiling time.

Table 51. Canned rice color response to variety x parboil interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
Parboil	Main effect	-0.52	0.87	0.10	-0.45
		Interaction			
Raw	-1.66	0.34	-1.55	0.52	0.69
2.5 Min.	-0.71	-0.65	0.23	0.14	0.28
5.0 Min.	-0.34	-0.17	0.18	-0.04	0.03
10.0 Min.	1.05	0.18	0.78	-0.20	-0.76
15.0 Min.	1.66	0.30	0.36	-0.42	-0.24

7. Variety x pH - As shown in Table 52, the total effect for all varieties except Texas Patna was to have the best color at pH 6.5.

Table 52. Canned rice color response to variety x pH interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
pH	Main effect	-0.52	0.87	0.10	-0.45
		Interaction			
4.5	0.73	-0.55	-0.35	0.70	0.20
6.5	-0.48	0.40	0.12	-0.36	-0.16
8.5	-0.25	-0.15	0.23	-0.34	0.26

Texas Patna was nearer the white standard at pH 8.5. This deviation from normality was the result of a strong interaction at pH 6.5 for Texas Patna to produce higher color readings. Century Patna 231 interacted negatively with pH increases; the reaction of

Belle Patna resulted in a lower color reading at pH 6.5 than 8.5; Jojutla tended to increase in color with the rise in pH.

8. Parboil x calcium lactate - The "F" test for this interaction was significant. However, the main effects are so strong that the interaction is of small consequence except for the zero level of parboiling (Table 53).

Table 53. Canned rice color response to parboil x calcium lactate interaction.

Treatment	Parboil	Raw	2.5 Min.	5 Min.	10 Min.	15 Min.
Calcium lactate	Main effect	-1.66	-0.71	-0.34	1.05	1.66
				Interaction		
0.00	-0.66	0.51	-0.28	-0.17	-0.03	-0.03
0.25%	0.26	-0.31	0.10	0.13	0.03	0.05
0.50%	0.40	-0.20	0.18	0.04	0.00	-0.02

The total effect for the raw rice was a slight upward trend in color with the increase in calcium lactate. All other parboiling treatments caused the color to increase sharply from the zero calcium lactate level to the 0.25 percent level and then to increase in color only slightly to the 0.50 percent level.

9. pH x calcium lactate - The pH of 4.5 reacted strongly with calcium lactate to produce higher color readings in both total and interaction effects. The interaction presented in Table 54 shows pH 6.5 and 8.5 with trends to lower color readings at the higher levels of calcium lactate.

Table 54. Canned rice color response to pH x calcium lactate interaction.

Treatment: Calcium lactate	pH: Main effect	4.5	6.5	8.5
Main effect		0.73	-0.48	-0.25
		Interaction		
0.00	-0.66	-0.56	0.27	0.29
0.25%	0.26	0.00	0.06	-0.06
0.50%	0.40	0.56	-0.33	-0.23

The total effects were virtually similar and the zero level of calcium lactate resulted in the best color. Small differences in color between the 0.25 percent and 0.50 percent calcium salt treatment were noted.

10. Calcium lactate x blanch - For the zero level of calcium, the effect of longer blanch time was a reduction in color values (Table 55).

Table 55. Canned rice color response to calcium lactate x blanch time interaction.

Treatment: Blanch	Calcium lactate: Main effect	0.00	0.25%	0.50%
Main effect		0.73	-0.48	-0.25
		Interaction		
10 Min.	-0.04	0.21	-0.09	-0.12
15 Min	-0.18	0.07	0.13	-0.20
20 Min.	0.22	-0.28	-0.04	0.32

At the 0.25 percent calcium lactate level, the total effect was a slightly increased color reading at the longer blanch times. The 0.50 percent calcium treatment resulted in the best color at the 15 minute blanch time and a greater color reading at the 20 minute level.

Analysis VI: Shear press - The L.E.E.-Kramer Shear Press was employed to provide objective data concerning the firmness of canned rice kernels. The analysis of variance is shown in Table 56.

Table 56. Analysis of variance - shear press.

Source	Degrees of freedom	Mean square	F
Total	505	152.95	13.05**
Variety	3	14997.74	1279.56**
Parboil	4	3311.32	282.51**
pH	2	745.12	63.57**
Calcium lactate	2	175.22	14.95**
Blanch time	2	106.32	9.07**
Variety × parboil	12	476.18	40.63**
Variety × pH	6	204.75	17.47**
Variety × calcium lactate	6	62.59	5.34**
Variety × blanch	6	7.58	0.65N.S.
Parboil × pH	8	57.52	4.91**
Parboil × calcium lactate	8	57.63	4.92**
Parboil × blanch	8	11.77	1.00N.S.
pH × calcium lactate	4	230.83	19.69**
pH × blanch	4	16.80	1.43N.S.
Calcium lactate × blanch	4	27.98	2.39**
Residual	426	11.72	----

Response scale tables for each significant main effect and interaction in Table 56 are presented and interpreted as follows:

1. Varieties - As shown in Table 57, textural differences due to varieties were quite striking.

Table 57. Shear press response to varietal differences.

Variety :	Texas Patna	Jojutla	C.P. 231	Belle Patna
Response :	0.51	15.90	-7.48	-8.93

The shear press response range for varieties was the widest of all the analyses. Of interest is the fact that Belle Patna was less firm than Century Patna 231. This situation was unexpected because Belle Patna recently has been marketed as a canner's quality rice and has gained acceptance for this use by certain canners. Results of the other analyses indicated Belle Patna to be a more favorable canned product than Century Patna 231. Belle Patna exhibited better over-all quality than Century Patna 231, but it was obvious during the evaluation procedure that Belle Patna became very soft in texture under the conditions of this study.

2. Parboiling - The parboiling treatments resulted in a steady improvement in texture with increased steaming times (Table 58).

Table 58. Shear press response to parboiling treatments.

Parboil :	Raw	2.5 Min.	5 Min.	10 Min.	15 Min.
Response :	-7.24	-2.94	-1.21	5.15	6.43

The large range between the 5 and 10 minute treatments indicated that the most efficient parboiling time occurred between these limits. Perhaps slight additional textural improvements could be obtained by increasing the treatment above 15 minutes, but the additional cost would likely be prohibitive.

3. pH - As before, the acid activity at pH 4.5 resulted in undesirable changes in the canned rice quality. The texture of rice canned at pH 6.5 and 8.5 was similar, while the rice canned at pH 4.5 was notably less desirable (Table 59).

Table 59. Shear press response to pH differences.

pH	:	4.5	6.5	8.5
Response	:	-2.42	1.15	1.27

4. Calcium lactate - As indicated in Table 60, the addition of calcium lactate to the fill liquid resulted in destructive rather than constructive effects.

Table 60. Shear press response to calcium lactate treatments.

Calcium lactate	:	0.00	0.25%	0.50%
Response	:	1.16	-0.44	-0.72

Acid hydrolysis at the lower pH's in combination with calcium lactate as well as a sloughing action by the salt itself resulted in less firm rice kernels when the salt was added to the fill.

5. Blanch time - In contrast to the previous analyses, the medium blanch of 15 minutes does not produce the best results as far as texture is concerned (Table 61).

Table 61. Shear press response to blanch time differences.

Blanch time :	10 Min.	15 Min.	20 Min.
Response :	0.91	-0.39	-0.52

From the standpoint of leachable solids remaining in the grain, it is logical to predict that the process with the least cooking or retorting time would result in the most firm rice. Such was the case in that as the blanch time increased, the firmness of grain decreased.

6. Variety x parboil - As indicated in Table 62, the total effects followed the strong trend set by the main effects. That is, increased firmness resulted with longer parboiling times for all varieties. Interaction-wise, Jojutla failed to respond strongly until the 5.0 minute treatment. It then showed strong tendencies for increased firmness, especially at the 10 and 15 minute treatments. The interaction tendencies of Century Patna 231, Belle Patna, and Texas Patna detracted from the main effect of increased firmness with the longer times.

Table 62. Shear press response to variety x parboil interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
Parboil	Main effect	0.51	15.91	-7.48	-8.93
		Interaction			
Raw	-7.43	-0.19	-4.21	0.93	3.47
2.5 Min.	-2.94	-0.17	-5.58	2.06	3.69
5.0 Min.	-1.21	2.43	-3.08	-1.31	1.96
10.0 Min.	5.15	-1.55	4.98	0.04	-3.47
15.0 Min.	6.43	-0.52	7.89	-1.72	5.65

7. Variety x pH - The interactions presented in Table 63 show different responses to pH for the four varieties used in this study.

Table 63. Shear press response to variety x pH interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
pH	Main effect	0.51	15.90	-7.48	-8.93
		Interaction			
4.5	-2.42	0.08	-3.37	2.84	0.45
6.5	1.15	-0.27	2.04	1.59	-3.36
8.5	1.27	0.19	1.33	-4.43	2.91

Jojutla interacted strongest in a positive direction at pH 6.5; Century Patna 231 showed a strong positive interaction at pH 4.5; Belle Patna interacted strongest in a positive direction at pH 8.5 and Texas Patna exhibited little interaction at all. The total effect trend was for lower shear press readings at pH 4.5.

8. Variety x calcium lactate - Except for Century Patna 231, which showed a strong positive interaction, the trend in total effects, as shown in Table 64, for each variety was a slight decrease in firmness with the addition of calcium lactate to the fill liquid.

Table 64. Shear press response to variety x calcium lactate interaction.

Treatment	Variety	Texas Patna	Jojutla	C.P. 231	Belle Patna
Calcium lactate	Main effect	0.51	15.90	-7.48	-8.93
		Interaction			
0.00	1.16	0.11	1.67	-1.78	0.00
0.25%	-0.44	-0.10	-0.71	-0.71	0.10
0.50%	-0.72	-0.01	-0.96	1.07	-0.10

With the addition of calcium lactate, the texture of Century Patna became slightly better than that of Belle Patna. Such action was not anticipated, nor can it be explained from the information at hand.

9. Parboil x pH - The total effect trend for all parboilings except the 10 minute treatment was for the best texture to occur with fill liquids at pH 6.5 and a slight decline in firmness at pH 8.5. In total effect, the pH of 4.5 universally resulted in the least firm samples of canned rice (Table 65).

Table 65. Shear press response to parboil x pH interaction.

Treatment	Parboil	Raw	2.5 Min.	5 Min.	10 Min.	15 Min.
pH	Main effect	-7.43	-2.94	-1.21	5.15	6.43
		Interaction				
4.5	-2.42	0.00	-1.55	1.76	0.45	-0.66
6.5	1.15	0.92	0.37	-0.68	-1.26	0.65
8.5	1.27	-0.92	1.18	-1.08	0.81	0.01

10. Parboil x calcium lactate - As indicated in Table 66, the response to calcium lactate by all parboilings was similar except for the raw rice control. The addition of calcium lactate to the fill liquid resulted in a decrease in firmness of grain. The unparboiled sample experienced an increase in kernel firmness with the addition of calcium lactate. The reason for this dissimilar action is not known. Kertesz (15) reports small quantities of pectic substances to be present in the rice grain. It is possible that the pectic substances were active in the raw rice, but they were denatured during the high temperature parboiling process. In fact, the short parboiling time of 2.5 minutes exhibited a smaller decrease in firmness than did the samples with longer parboiling times. The firming action of calcium lactate on the raw rice was not great and, therefore, it is not possible to postulate whether or not there may have been a firming reaction between the pectic substances in the rice grain and the calcium lactate in the fill liquid.

Table 66. Shear press response to parboil x calcium lactate interaction.

Treatment	Parboil	Raw	2.5 Min.	5 Min.	10 Min.	15 Min.
Calcium lactate	Main effect	-7.43	-2.94	-1.21	5.15	6.43
		Interaction				
0.00	1.16	-2.51	0.47	0.96	0.09	-0.99
0.25%	-0.44	1.58	-0.40	-0.28	-0.56	-0.34
0.50%	-0.72	0.93	-0.07	-0.68	-0.47	-0.65

11. pH x calcium lactate - Of all the analyses the shear press readings most vividly showed the action of the excess acid at pH 4.5 in the presence of calcium lactate (Table 67).

Table 67. Shear press response to pH x calcium lactate interaction.

Treatment	pH	4.5	6.5	8.5
Calcium lactate	Main effect	-2.42	1.15	1.27
		Interaction		
0.00	1.16	2.67	-1.33	-1.34
0.25%	-0.44	-1.28	0.63	0.65
0.50%	-0.72	-1.39	0.70	0.69

As was explained previously, the quantity of acid sufficient to reduce the pH of the calcium lactate solutions to 4.5 resulted in acid hydrolysis of the rice starch. As a result, the texture of all samples with calcium lactate added and a pH of 4.5 was quite undesirable.

12. Calcium lactate x blanch - As shown in Table 67, the interaction and consequently the total effects for calcium lactate and blanch time were somewhat erratic.

Table 68. Shear press response to calcium lactate x blanch time interaction.

Treatment	Calcium lactate	0.00	0.25%	0.50%
Blanch	Main effect	1.16	-0.44	-0.72
			Interaction	
10 Min.	0.91	0.85	-0.68	-0.17
15 Min	-0.39	-0.40	-0.49	-0.09
20 Min	-0.52	-0.45	-0.19	-0.26

The general trend in total effects for all calcium treatments was for reduced firmness with increased blanch times. The interaction effects of the 0.25 percent and 0.50 percent calcium lactate indicated a trend for increased firmness with the addition of calcium salts.

Optimum Process Formulation

An objective of this study was to formulate a canned rice process which would benefit from the optimum combination of the processing variables applied. Each criterion of canned rice quality cannot be satisfied without the sacrifice of some other desired characteristic. An example of this is the fact that parboiling simultaneously toughens and colors the rice grain (Figure 4). The color is undesirable, but the improvement in texture far outweighs the detrimental color effect.

In order of suitability for use in liquid canned formulations, the varieties of this study were Jojutla, Texas Patna, Belle Patna, and Century Patna 231 (Figure 5).

The optimum combination of quantitative processing variable for each of the six recorded criteria of quality are presented in Table 69.

Table 69. Optimum levels of processing variables.

	D.W.	T_1	T_2	R	Color	S.P.
Parboiling	15 Min.	15 Min.	15 Min.	15 Min.	Raw	15 Min.
pH	6.5	8.5	4.5	4.5	6.5	6.5
Calcium lactate	0.00	0.00	0.00	0.00	0.00	0.25
Blanch time	15 Min.	15 Min.	15 Min.	15 Min.	15 Min.	15 Min.

D.W. - Drained weight.
T_1 - Turbidity of undisturbed liquid.
T_2 - Turbidity of agitated liquid.
R - Subjective rating.
S.P. - Shear press texture readings.

In every instance, the 15 minute blanch time resulted in the most favorable canned rice quality. The addition of 0.25 percent calcium lactate at pH 6.5 produced the highest shear press readings for firmness. The difference, however, between firmness at pH 6.5 and 0.25 percent calcium lactate and the readings at pH 4.5 and no calcium treatment is small. It is doubtful that the slight textural benefit from the addition of calcium lactate would offset the detrimental

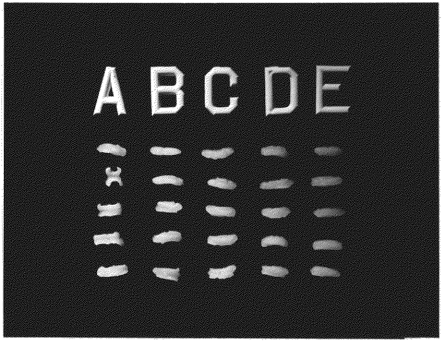

Figure 4. Parboiling treatment effect on Jojutla variety. From left to right: raw, 2.5 minute steam, 5.0 minute steam, 10.0 minute steam, and 15.0 minute steam.

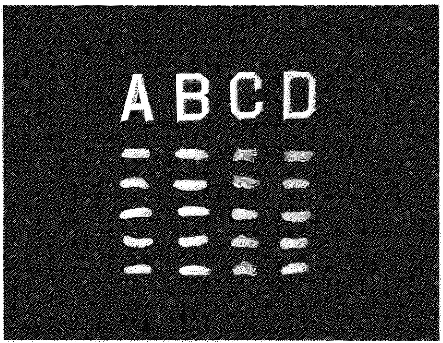

Figure 5. Varietal differences at 10.0 minute parboiling steam time. From left to right: Jojutla, Texas Patna, Century Patna 231 and Belle Patna.

effect exerted on color and turbidity. Similarly, raw rice produced the whitest color, but is unusable from the other quality standpoints. The pH of 6.5 appears to give the best overall response.

The general recommendation resulting from the study at hand for the canning of long-grain rice in a liquid medium is a parboiling steam time of near 15 minutes, adjustment of the canning liquid to a pH near 6.5, blanching of rice at 205° F. for approximately 15 minutes prior to canning and retorting at sterilization times and temperatures commensurate with the product involved.

It may be pointed out that the surface smoothness of canned rice can perhaps be enhanced by soaking in cool water for several hours prior to blanching. This treatment allows gradual hydration which eliminates surface rupturing when the rice is inserted directly into water at 205° F. (14).

CHAPTER V

SUMMARY AND CONCLUSION

It is apparent that liquid medium canned rice processing conditions are influenced mainly by variety and parboiling treatment and in a minor way by other technological variables. This investigation concerned the effect of varieties, parboiling, pH, calcium lactate concentration, and blanch time in terms of texture and appearance of canned rice in a liquid medium.

Summary of Results

Drained weight. Drained weight, an indication of water uptake, should be minimal. Low readings, however, can occur when kernel disintegration detracts from the drained weight solids. The Jojutla variety exhibited very low drained weights in comparison to the other varieties. Texas Patna was second lowest, Belle Patna third, and Century Patna 231 absorbed the greatest amount of water. Increased parboiling times resulted in decreased drained weights.

The adjustment of fill liquid pH to 6.5 gave the best drained weight response as compared to pH 4.5 and 8.5. Samples with calcium lactate and a pH of 4.5 produced undesirably low drained weights because of kernel sloughing due to acid hydrolysis. Calcium lactate in combination with higher pH's had little effect on drained weight. For all varieties, drained weight tended to decrease as blanch time increased. Kernel disruption was enhanced by blanch times longer than near the 15 minute interval.

Turbidity of the undisturbed fill liquid. The least turbid canning liquor came from Jojutla rice which had been steamed 15 minutes during parboiling. The other varieties ranked in order of increasing turbidity are: Texas Patna, Belle Patna, and Century Patna 231. Results indicated that the treatment consisting of pH of 8.5, no calcium lactate and a blanch time of 15 minutes yields the clearest canning liquor of any combination of these variables.

Turbidity of the agitated fill liquid. Excepting pH, the processing variables applied in this study had the same effects aswere observed on the turbidity of the undisturbed liquid. At a pH of 4.5, the sloughed grain materials were apparently hydrolyzed, giving a less turbid agitated broth than did pH 6.5 or 8.5. The addition of calcium lactate to the fill liquid produced a sloughing action at all pH levels. This sloughing action is apparently similar to that encountered by Ghosh and Sarbor (9). Results of this study indicated that a 15 minute parboiling time, a pH of 4.5, a calcium lactate treatment of zero and a 15 minute blanch will result in the least turbid agitated canning liquor regardless of variety.

Subjective rating. Irregardless of treatment, the relative ranking of the different varieties remained rather constant. Jojutla usually ranked good, while Century Patna 231 was uniformly poor. Certain differences between treatments were discernable. For instance, the application of longer steam times resulted in a steady gradient of textural improvement through the longest time of 15 minutes. The treatment at pH of 4.5 yielded best results mainly because the acidic action produced smoother grain surfaces. The addition of calcium lactate and blanch times greater than 15 minutes were detrimental.

Canned rice color. The most desirable variety and the most desirable parboiling treatment resulted in the least desirable color. Whiteness of grain is desired, but the textural advantages of parboiling offset any detrimental color effects. Raw rice, of course, exhibits the whitest color. The treatment consisting of pH 6.5, no calcium lactate, and a blanch time of 15 minutes in combination was not detrimental to the color of any raw or parboiled variety.

Shear press. Firmness of grain is one of the most important criteria of canned rice quality. Firmness and length of steam times during parboiling were shown to be directly related. Jojutla was the most firm variety, Texas Patna second, Century Patna 231 third, and Belle Patna the least firm of all. The ranking of Belle Patna was not expected since it is widely used commercially for canning purposes. The application of calcium lactate at pH 6.5 and 8.5 was of little consequence, however, the solutions of calcium lactate which were adjusted to pH 4.5 resulted in acid hydrolysis and undesirable textural conditions. From the standpoint of firmness, the shortest blanch time, 10 minutes, was found to be best.

Conclusions

Jojutla was the best suited of the four rice varieties studied for canning in liquid formulations.

Century Patna 231 and Belle Patna varieties were unsuited for use in the canned formulations of this study.

Texas Patna rice was of acceptable quality and can be used in liquid canned formulations.

Severity of parboiling treatments was directly related to improved rice texture and appearance.

A median pH near 6.5 was optimum for liquid canned rice products.

The addition of calcium lactate salt to the fill liquid afforded no constructive effects and caused a certain degree of kernel disintegration.

A blanch time near 15 minutes was optimum for canned rice products.

The initial color of the rice hull had a direct effect on the final color of the rice endosperm after parboiling treatments.

LITERATURE CITED

1. Anonymous. 1958. Manual for Gardner AC-2 color and color difference meter. Gardner Laboratory Inc., Bethesda, Maryland.

2. Barlowe, Raleigh. 1958. Land Resource Economics. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

3. Batcher, O. M., Helmintoller, K. F., and E. H. Dawson. 1956. Development and application of methods for evaluating cooking and eating quality of rice. Rice Journal 59(13):4-8.

4. Dawson, E. H., Batcher, O. M., and Little, R. R. 1960. Cooking quality of rice. Rice Journal 63(5):16-22.

5. Desikachar, H. S. R. 1956. Changes leading to improved culinary properties of rice on storage. Cereal Chemistry 33(5):324-328.

6. Desikachar, H. S. R., and Subrahmanyan, V. 1960. The relative effects of enzymatic and physical changes during storage on the culinary properties of rice. Cereal Chemistry 37(1):1-8.

7. Ferrel, R. E., Kester, E. B., and Pence, J. W. 1960. Use of emulsifiers and emulsified oils to reduce cohesion in canned white rice. Food Technology 14(2):102-105.

8. Freund, R J. 1964. Personal communication. Assistant Director of Texas A&M University Statistics Institute. College Station, Texas.

9. Ghosh, B. P., and Sarbar, N. 1959. Effect of some inorganic salts on water absorption by rice during cooking. Ann. Biochem. Exp. Med. 19:83-86.

10. Halick, J. V., and Keneaster, K. K. 1956. The use of a starch-iodine blue test as a quality indicator of white milled rice. Cereal Chemistry 33(5):315-319.

11. Hodges, R. J. Jr. Rice--a big business on the gulf coast prairie. Texas Agri. Ext. Serv. Bul. 872.

12. Hylander, C. J. 1939. The World of Plant Life. McMillan Co. New York.

13. Jones, J. W. 1946. Effect of parboiling and related treatments on the milling, nutritional, and cooking quality of rice. U.S.D.A. Circ. 752. Wash. D.C.

14. Keneaster, K. K. 1964. Personal communication. Director of product research and development. Uncle Ben's Inc., Houston, Texas.

15. Kertesz, Z. I. 1951. The Pectic Substances. Interscience Publishers. New York.

16. Kertesz, Z. I. 1950. A simple turbidity tester. The Canner 110(20):15-16.

17. Kester, E. B. 1959. The chemistry and technology of cereals as food and feed. Edited by S. A. Matz. Avi Pub. Co., Westport, Conn.

18. Kincannon, John A. 1957. Rice supply, demand and related government programs. Texas Agri. Exp. Sta. Bul. 850.

19. Kramer, Amihud. 1957. Food texture rapidly gaged with versatile shear-press. Food Engineering 29(5):57.

20. Little, R. R., Hilder, G. B., and Dawson, E. H. 1958. Differential effect of dilute alkali on 25 varieties on milled white rice. Cereal Chemistry 35(2):111-126.

21. Little, R. R., and Hilder, G. B. 1960. Differential response of rice starch granules to heating in water at 62° C. Cereal Chemistry 37(4):456-463.

22. Little, R. R., and Dawson, E. H. 1960. Histology and histochemistry of raw and cooked rice kernels. Food Research 25(5): 611-622.

23. Matz, S. A. 1962. Food Texture. Avi Pub. Co., Westport, Conn.

24. Mogford, J. S., and Corns, J. B. 1958. Production of farm crops. The Exchange Store. College Station, Texas.

25. Reynolds, E. B. 1954. Research on rice production in Texas. Texas Agri. Exp. Sta. Bul. 775.

26. Roberts, R. L., Houston, D. F., and Kester, E. B. 1952. Process for canning white rice. Food Technology 7(2):78-80.

27. Roberts, R. L., Potter, A. L., Kester, E. B., and Keneaster, K. K. 1954. Effect of processing conditions on the expanded volume, color and soluble starch of parboiled rice. Cereal Chemistry 31(2):121-129.

28. Steel, R. G. D., and Torrie, J. H. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Company, New York.

29. Webb, B. D. 1963. Personal communication. U.S.D.A. research chemist. Texas Agri. Exp. Substation 4. Beaumont, Texas.

30. Wigman, H. B., Leathen, W. W., and Brackenbayer, M. J. 1956. Phase contrast microscopy in examination of starch granules. Food Technology 10(4):179-184.

31. Williams, V. R., Wei-Ting, W. A., and Tsai, Hsiuy. 1958. Varietal differences in amylose content of rice starch. J. Agric. Food Chem. 6:47-48.

32. Younkin, S. G. 1950. Color measurement of tomato purees. Food Technology 4(9):350-353.