EFFECTS OF INGREDIENT VARIABLES AND FORMULA OPTIMIZATION FOR RICE BREAD WITH SOY FLOUR SUBSTITUTION

by

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INTRODUCTION

Rice (Oryzae sativa) is one of the most important grains for the world's inhabitants. It is the main cereal grown in most Asian countries. In areas in which rice is a principle food, products made from rice are many and varied. In the United States, the range of rice products is more limited. Broken rice is used mainly as a brewing adjunct or is processed as a breakfast cereal or thickening agent.

Rice flour is produced by grinding broken milled white rice. Flour from rice is used primarily as a dusting flour or in baby food. However, many people who are allergic to the proteins in wheat flour can use rice flour as a cereal substitute in their diets. Conversion of rice flour into an acceptable bread would provide another excellent use for rice.

Despite absence of gluten protein in rice flour, Nishita et al. (1976) developed a 100% rice flour bread that is now used successfully in commercial and home applications. Varietal differences in flour characteristics such as amylose content and gelatinization temperature have been shown to affect the quality of rice flour breads (Nishita and Bean 1979).

Rice-bread formulas differ from wheat-bread formulas in several ingredients. An optimum rice-bread formula developed by Nishita et al. (1976) included rice flour, yeast, salt, sucrose, oil, methylcellulose, and water. Shortenings and surfactants as dough conditioner were tested for the formula development, and were found to have an adverse effect on the rice bread quality. However, a literature search failed to identify the effect of oxidizing agents in rice bread, although these agents are commonly used in conventional bread-making to provide greater volume and to improve internal bread characteristics such as grain and texture.

Soy flour is an excellent source of protein to supplement rice flour because it has a high protein content and a good balance of essential amino acids. Since much research had been done on substitution of various proportions of soy flour for wheat flour in breads, it was considered of interest to study the substitution of some soy flour in a yeast-leavened rice bread.

Statement of the Problem

The purposes of this study were to determine the effects of ingredient variables on the quality of a yeast-leavened rice bread, and to optimize a formula for a rice-bread containing soy flour.

Specifically, the objectives of this investigation were to:

1. Determine the effect of different levels of hydroxypropyl methylcellulose (HPMC)* on the pasting characteristics of rice flour which could influence the quality of rice bread.
2. Determine the effect of ingredients (salt, sugar, and HPMC) on the gas production of yeast in rice flour.
3. Determine the effect of an oxidant (potassium bromate) on the loaf volume of rice bread.
4. Find out the effect and the maximum level of soy flour which could be substituted into rice flour without seriously affecting rice bread quality (volume).
5. Optimize a formula for a rice bread in which a part of the rice flour was substituted with soy flour.

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* Hydroxypropyl methylcellulose (HPMC) used in this study is identified as Methocel (R) K4M (90HG 4000).
(R) indicates a trademark of The Dow Chemical Company.

REVIEW OF LITERATURE

Rice Flour

Types of flour. Through history, people have milled various cereal grains to flours. Presently, there are two types of commercial rice flour available in the United States (Luh and Liu 1980). The first is produced from waxy or glutinous rice, which is commercially grown in limited quantities in California. The other type of rice flour is prepared from broken grains of ordinary raw or parboiled rice.

Ordinary rice is identified by its grain length: long, medium, and short. When rice is cooked as whole kernels, long-grain rices give a dry and fluffy texture; short and medium grain give soft, sticky structures; waxy rices give very sticky structures (Bean 1986). Rice flours made from long, medium, and short grain and waxy rice are commercially available.

Physicochemical properties. Differences in textural properties for cooked rice have been shown to be directly related to some of the inherent properties of rice starch, particularly the amylose content (Webb 1985). Some of the physicochemical characteristics that influence the eating quality of the parent rices are also found in the flours and reflected in baked products. Therefore, a study of the flour properties focuses principally on starch characteristics.

In choosing rice cultivars for flour, consideration must be given to the amylose/amylopectin ratio and to the gelatinization temperature of the starch. According to Nishita and Bean (1979), rice flours with low amylose content, low gelatinization temperature, and low amylograph viscosity upon cooling to 50° C (set back) produced rice breads with superior crumb properties. However, rice bread cannot be produced from waxy rice flour alone. Up to 25% nonwaxy flour may be replaced with waxy rice flour without seriously affecting loaf volume (Nishita and Bean 1979).

<u>Milling effect</u>. In addition to inherent starch properties, another factor imposing variation on functional properties of rice flours is the milling or grinding method used to make the flours. With dry milling, the types of mill or grinder used affected the particle size and functional properties of rice flour (Nishita and Bean 1982). They found that coarser flours had less damaged starch and functioned better in 100% rice flour breads, whereas the finer flours had high levels of starch damage and did not function well in yeast-leavened breads. Water absorption capacity was greater for fine flours.

Increasing the water absorption to accomodate the damaged starch produced a softer dough with moderate increase in volume, but with poor crumb quality due to the excessive water requirement (Bean 1986).

Nutritive value of rice flour. Since rice flours are made from broken milled rice, their chemical composition is the same as whole rice (Appendix 1). There are, however, varietal differences in protein, lipid, starch contents and amylose/amylopectin ratios.

Starch, usually calculated as available carbohydrate in nitrogen-free extracts, is the major component of rice flour. Rice flour has a low protein content, compared with most of the other cereal grains, although its protein ranks high in nutritive quality. Lysine is the first limiting amino acid in rice proteins, based on the FAO/WHO reference amino acid pattern (Juliano 1985). In practice, cereal grains are consumed in diets with other protein sources. Cereal-legume mixtures are nutritionally complementary, because legumes are rich in lysine but deficient in cystine and methionine, whereas cereals are poor in lysine but rich in cystine and methionine (Juliano 1985).

Rice flour is relatively low in lipid content. Of the vitamins present in rice flour, thiamin and niacin are probably the most important (Kennedy 1980). Among the major mineral constituents in rice flour are phosphorus, potassium, silicon, magnesium, calcium, sodium and iron. Minerals and vitamins are generally present in higher levels in brown than in milled rice (Appendix 1).

Use of rice flour. Although no official statistics exist for rice flour manufacture and consumption, rice flour is a growing market with many diverse food applications. Major uses are baby foods, extruded breakfast cereals, and snack food. About 5-10% of total production is used in a variety of baking applications. As rice is noted for its nonallergenic properties, it is the first cereal recommended for infants (Bean and Nishita 1985).

Products called "rice cakes" are made in many cultures and have a wide range of processing and product characteristics. A layer cake formula containing 100% rice flour was developed by Bean et al. (1983) for use in wheat free diets. Rice flour can be used in composite flours. Some composite flours may be comilled, but more frequently they are blended after milling or during dough preparation at a bakery. Technology for making composite flours and baked products has been developed extensively since the 1960s to increase the nutritional and calorie intake in developing countries (Bean and Nishita 1985).

Rice Bread

Origin of rice bread. The use of rice flour for baking was probably motivated by the recognition of its usefulness as a substitute for wheat in the dietary treatment of wheat-intolerant patients. Small segment of the population suffers from dietary wheat intolerance, which includes celiac disease (also termed celiac sprue, nontropical sprue, or gluten enteropathy), and related less well-defined wheat intolerances and allergies (Kulp et al. 1974).

Celiac disease, an inherited disorder, is estimated to affect one out of each 2,500 persons in the United States (Hartsook 1984). The actual number may be greater. The most frequently reported symptoms of celiac disease include diarrhea, pale bulky stools, abdominal cramps, flatulence, and weight loss or a failure to grow (Kasarda 1972). A depression of many enzymes associated with the epithelial cells of the small intestine has been noted in celiac disease. Malabsorption of almost all nutrients is also characteristic.

The responsible pathogenic factor of wheat has been traced to the gliadin fraction of gluten which damages the lining of the small intestine. Accordingly, patients are advised to omit gluten-containing foods from their diets. In addition to wheat gluten, proteins of rye, oats, and barley are also objectionable and cannot be used as gluten substitutes (Kulp et al. 1974, Sleisenger et al. 1957), because they are also responsible for celiac disease. Corn and rice products have usually been considered nontoxic to celiac patients (Kasarda 1972).

Development of rice bread. The problems associated with rice bread formulation are primarily due to the absence of gluten proteins in rice flour. The manufacture of rice bread without gluten presents considerable technological difficulties, because gluten is the important structure-forming protein (Kulp et al. 1974). Endosperm wheat proteins possess the unique and distinctive property of forming gluten when mixed with water. When water is added to wheat flour and mixed, the water-insoluble proteins hydrate and form gluten, a complex coherent mass, in which starch, added yeast, and other dough components are embedded. Thus, the gluten is, in reality, the skeleton or framework of wheat-flour dough. The formation of a structure in wheat dough that will not only retain the gas produced by the yeast but which is also in a suitable extensible form, so that it may expand during the proof and early baking stages is important to fermented bread production (Dubois 1984).

The use of various gluten substitutes in producing acceptable breads from starches and certain nonwheat flours had been discussed in a large number of articles (Steele et al. 1965, Mcgreer 1967, Jongh et al. 1968, Kim and de Ruiter 1969, Christiansen et al. 1974, Hart et al. 1970). By adapting the basic concepts developed in these studies, Nishita et al. (1976) developed a yeast-leavened bread formula made from 100% rice flour. They compared the effect of gums such as hydroxypropylmethylcellulose (HPMC), locust, guar, sodium carboxymethylcellulose, carrageenan and xanthan gums as a gluten substitute on the loaf volume of rice bread.

Of the gums, the HPMC showed the most promise for improving gas retention in rice-bread dough, since it appeared to provide the rice dough with the viscosity necessary to retain fermentation gases and the "water-release" effect needed for starch gelatinization. This effect parallels that of hydrated gluten in wheat bread, where water is released during heat denaturation and made available for gelatinization (Bushuk 1966).

Plastic fats and surfactants, which normally improve wheat breads, had negative effects on the rice dough and bread. Only refined oil, such as corn, cottonseed, soy, safflower, or similar oils, may be used in rice bread formulations (Nishita 1983). The proportion of rice flour, methylcellulose, and water content was especially critical, since insufficient water produced a dense loaf; on the other hand, excess water produced a blown-up loaf (Nishita et al. 1976). Insufficient water made a very stiff dough which did not rise well during proofing. The bread volume was low and the loaf was compact. Each additional increment of water made the dough slightly softer and increased proof height as well as bread volume. Excessive water caused overexpansion during baking. The resulting large-volume loaves contained big holes, which became progressively enlarged and more numerous as the amount of water was increased. Therefore, it should be stressed that all ingredients should be measured accurately.

According to Nishita et al. (1976), 100% rice bread has a golden brown, chewy crust with a bland, moist, white crumb. Its specific volume is between 4 and 5 cc per gram of bread, compared with about 6 cc per gram for American white bread and 4 cc per gram for European bread (Pomeranz 1969). Since rice bread has a relatively short shelf life, it is best when prepared as needed at the point of use. The bread can be frozen and toasted before using. A dry mix containing most of the ingredients would offer the greatest convenience.

Components affecting bread functionality. Rice proteins occur in the endosperm, chiefly as intact spherical protein bodies. They are not easily disrupted in water and retain their shapes in the fractionation and separation steps which are necessary for their isolation. This behavior is in contrast to the fibril formation (Bernardin and Kasarda 1973) when wheat flour is wetted. However, Bean et al. (1983) explained that a potential wheatlike structure might be formed in rice flour during mixing and hydration with water, if kneading rice flour doughs might bring about formation of "gel" proteins. The rice starch granules may contribute to the limited ability of rice flour to yield bread (Nishita et al. 1976). The granules are the smallest (4-8 μ) of the common starches and the gelatinization properties are quite different from wheat starch. Lipids might be involved in rice flour changes, as they are found intimately associated with isolated protein bodies.

Effect of Oxidants

Wheat flour bread made without oxidants has a tendency to be more dense and to have a reduced volume compared with that produced using oxidants. The oxidants are used to strengthen the dough by improving the protein network which, in turn, yields better gas retention and ultimately leads to improved grain and texture. It is now generally accepted that the improved action results from the sulfhydryl-disulfide interchange reaction between protein molecules induced by oxidation, even though it doesn't explain all of the flour's oxidation requirements (Pyler

1988).

Oxidizing agents available for bread-making include potassium bromate, potassium iodate, calcium bromate, calcium iodate, azodicarbonamide (ADA), and ascorbic acid (Kamman 1984). Among them, potassium bromate ($KBrO_3$) was first used and continues as a basic oxidant.

Potassium bromate is permitted by FDA to be used at levels up to about 75 ppm. It reacts at a relatively slow rate and becomes active at lower pH levels and at high temperatures (Kamman 1984). The effects of potassium bromate are, therefore, noticed in the late stages of fermentation and in the early stages of baking. In the presence of moisture from the dough and heat from the oven, potassium bromate splits apart, forming the reduced form of the molecule, potassium bromide, and liberating oxygen to react with the sulfhydryl groups of gluten (Jackel 1977).

Despite an absence of gluten in rice flour, the effect of an oxidant on rice bread quality may be questioned from a study by Sullivan et al. (1963), who suggested that part of the improving action of oxidants may be accounted for by their reaction with the thiol groups of nongluten proteins, such as albumins.

Soy Flour Substitution

Soy Flour. One of the most common forms in which soybean protein is used in Western type diets is as a flour. Most soy flours and grits are prepared from dehulled beans and have similar chemical composition (Wolf and Cowan 1975). Soy flours are produced in the largest quantity, as compared to the other soy protein forms and, therefore are used to produce a wide variety of products with varing particle size, protein solubility and fat content. Soy flours are usually classified according to their fat content. The protein content of soy flours range from 43% to 53%, depending on the oil content (Waggle and Kolar 1979). The protein products produced from the soybean which are used in the largest volumes by food manufacturers are defatted soy flour grits (Kellor 1974). Defatted soy flour and grits are the most economical source of soy protein.

Nutritive value of soy flour. Among the oilseeds, the soybean assumes a most prominant position; not only is its protein content high, but the protein is of good nutritional quality (Liener 1978). Most soy protein amino acid levels equal or exceed the level in egg proteins, except for the sulfur amino acids which are low. Therefore, methionine should be added to soy protein, unless soy proteins are mixed with other protein, to provide an essential amino acid balance (Wolf and Cowan 1975). Although the principal contribution which the soybean can make to the nutrition of man lies in the quality and quantity of protein it contains, carbohydrate and oil components of the soybean should also be considered as caloric requirements for an undernourished population.

Soybeans contain all the known vitamins. Flour made from the whole soybean is an excellent source of vitamin A, and a good source of the vitamin B complex. The addition of soy flour to a rice diet would add vitamins and considerably improve the quality of the diet, particularly in regard to prevention of vitamin A and B complex deficiencies. Soy flour contains calcium, phosphorus, sodium, potassium, magnessium, and trace minerals such as iron, copper, cobalt and zinc.

Effects on baked products. Various types of soy flours are used in a wide variety of baked goods, at concentrations of up to 10% by weight of the wheat flour, and in some instances a 20% level has been recommended. Although concentrates and isolates have been experimentally incorporated into bread and other baked goods, defatted and full-fat soy flours are the primary forms used by the baking industry. Many bakers have used soy flours as a regular ingredient in their breads, and also as a partial repalcement for non-fat dry milk.

Soy flours have been used mainly for their water absorption and their ability to hold moisture, extending the shelf-life of the products (Turro and Sipos 1970). These functional properties and associated economies have interested bakers in using soy flour as an extender in cake batters or bread doughs. Batters or doughs containing soy flour have generally appeared stiffer than those prepared entirely from wheat flour. The baked products had finer grain and a softer texture. Due to the hydrophilic nature of soy flour, they tend to promote longer shelf life in baked products. The addition of soy flour in baked goods requires the addition of 1 to 2 times its weight of water. Soy flour has also the ability to give a rich color to baked products.

Soy flour is devoid of gluten; when added to bread dough, it places an added stress on the gluten, and if too much added, it will modify the structure of the bread and also reduce loaf volume. It is well recognized that present soy flours have a characteristic flavor, and when used in bread at too high a level they will introduce a foreign or unusual flavor which has a serious influence on its acceptance.

The nutritional value of baked products made with varying amounts of soy flour has been evaluated by many workers (Reynolds and Hall 1950, Tremple 1958, Wilding et al. 1968). In both animal and human experiments, the results indicate that subjects have superior growth rates, better PER, and increased nitrogen retention when soy flour is added to wheat flour. In short, adding soy flour to some baked foods can improve their nutritional value, cut their costs, and extend their shelf-life through moisture retention.

MATERIALS AND METHODS

Materials

Ingredients. Rice Flour RM-100, made from medium grain varieties, was donated by Riviana Food Inc., Houston, Texas, and stored at room temperature until needed. Elam's defatted soy flour was obtained from Elam Mills, Broadview, Illinois. Methocel K4M (90HG4000), a hydroxypropyl methylcellulose (HPMC) compound used in this study was donated by Dow Chemical Co., Midland, Mich. Wesson corn oil, Saf-Instant yeast, sugar, salt, and potassium bromate were obtained from the Baking Lab in the Grain Science Dept. at Kansas State University.

Equipment. Standard utensils were used in the preparation of rice bread. An electronic balance was used to weigh, to the nearest 0.1 g, the rice flour, soy flour, sugar, salt, HPMC, yeast, and oil. A pin mixer (NATIONAL MFG CO. Lincoln, Nebr.) with a small mixing bowl (200 g) was used to mix the ingredients. A fermentation cabinet was used for the fermentation of doughs. All bread loaves were baked in a Reed reel oven.

Determination of Amylograph Viscosity

VISCOGRAPH-Amylograph (C.E. Brabender Instruments, Inc.) was used in this study. A 10% slurry was prepared by dispersing 50 g of rice flour (14% m.b.) in 300 ml out of the required 450 ml of distilled water in a Waring Blender for 1 minute. The slurry was poured into the amylograph bowl. The remaining water was used to rinse the blender and then transferred to the amylograph bowl. The slurry was immediately heated to 30° C. The chart was then adjusted to a zero min marking and the slurry heated to 95° C at a rate of 1.5° C per min. The paste was held at this temperature for 20 min. and then cooled back to 50° C at the rate of 1.5° C per min.

To study the effects of different concentrations of HPMC on pasting characteristics of rice flour, different amounts of HPMC (0.5 g - 2.5 g) were substituted for rice flour, the total wt. of the mixture being 50 g (14% m.b.).

Determination of Gas Production

The method of Rubenthaler et al. (1980) was used, utilizing the gasograph (Demaray Scientific Instrument LTD. Pullman, WA). Given amounts of yeast, sucrose, salt, and HPMC were added to flours (10 g, 14% m.b.). Each sample was slurried for 1.5 min in a reaction bottle containing 15 ml of distilled water. The gasograph reaction bottles were stoppered 2 min after being placed in the waterbath. Waterbath temperature was kept at 30° C. The chart paper has 100 horizontal parallel lines. The distance between any two consecutive lines was one gasograph unit (GU). Chart speed was set at 1 division (1.27 cm)/10 min.

Gasograph units can be converted to millimeters of Hg simply multiplying by the factor F=7.3. Gas production in the gasograph also may be expressed in cubic centimeters by multiplying GU by 2.38 (Rubenthaler et al. 1980).

Rice Bread Preparation

Preliminary studies. Preliminary trials were conducted to determine approximate water absorption, HPMC level, mixing time, fermentation temperature, fermentation time, baking temperature, and baking time. The basic formula (Appendix 2) was modified from Nishita et al.(1976) and Nishita (1983) during the preliminary studies.

Material preparation. Dry ingredients (flours, salt, sugar, and HPMC) for each sample were weighed and bagged in a plastic bag the day before the baking trials. All bags were closed with twist-ties and stored at room temperature.

Water, oil, oxidant, and yeast were measured on the trial days. The oven was preheated to 375° F (191° C). The fermentation cabinet was preheated and controlled to 86° F and 87% relative humidity.

Bread making. Dry ingredients (flours, salt, sugar, yeast, and HPMC) were blended for 60 strokes and set aside. Water, oil, and oxidant were added to the mixing bowl. Two-thirds of the dry ingredient mixture was added to the liquid and mixed for about 15 seconds at speed of 120 rpm until the mixture was wetted. It was then mixed for 5 minutes at the same speed. Half of the remaining dry ingredients was slowly added with the mixer running and mixed well for 1.5 minutes.

The mixer was turned off, the remaining dry ingredients were added, and mixed as well as possible with a wooden spoon (for 1 min). The dough was then transferred to a piece of wax paper previously coated with 1 tsp. of oil and a constant weight of dough (180 g) was molded with hands into a loaf. Dough was placed in a well-greased loaf pan (140x80x60 mm), and allowed to proof for 1.5 hr or to a constant height of 76 mm in the fermentation cabinet. The bread was baked at 375° F (191° C) for 35 minutes, removed from the pan, and cooled at room temperature on a cooling rack.

Rice Bread Evaluation

Loaf volume was measured immediately after baking by the rapeseed displacement method. Each loaf was measured three times and averaged. After their volumes were measured by rapeseed displacement, their weights were determined, and specific volumes were calculated as loaf volume(cc)/baked loaf weight(g). The rice bread quality was also evaluated subjectively by judging its grain. It was scored on a scale of 1 - 10 (10 denotes the best quality; 1 denotes the lowest quality).

Experimental Design

The experimental work was divided into two stages. In the first stage, called screening, the objectives were to efficiently determine the critical control variables from eight ingredient variables (Table 1) and to observe the effect of each individual variable, especially oxidant ($KBrO_3$) and soy flour. A two-level (Table 2) fractional factorial design was best suited for this purpose.

In the second stage, the objective was to find the optimum levels of the critical control factors so that the desired product quality could be met. Response surface methodology, as described by Cochran and Cox (1957) was used for this purpose. Response surface analysis which was completed with a personal computer program (Walker and Parkhurst 1984) fits a full response surface model including all linear, interaction, and quadratic effects.

Table 1. Ingredient variables and their levels

[a]Ingredient variables	Symbol	Level code -1.000	Level code 1.000
Salt (%)	X1	1	3
Sugar (%)	X2	4	12
[b]HPMC (%)	X3	1	5
[c]Oil (%)	X4	4	8
Water (%)	X5	90	100
[d]Yeast (%)	X6	1	5
[e]Oxidant (ppm)	X7	0	60
[f]Soy flour (%)	X8	0	[g]6

a. Ingredients are based on 100 g of total flour

b. Methocel K4M (90HG 4000) Hydroxypropyl Methylcellulose

c. Wesson corn oil

d. Saf-Instant yeast

e. Potassium bromate

f. Elam's defatted soy flour

g. Rice flour : soy flour (94 g : 6 g)

Table 2. Fractional factorial design

Randomized obs. #	Controlled factor							
	X1	X2	X3	X4	X5	X6	X7	X8
1	1	1	1	1	-1	1	1	-1
2	-1	1	1	1	-1	-1	-1	-1
3	-1	1	-1	1	1	1	-1	-1
4	1	1	-1	-1	-1	-1	-1	-1
5	1	-1	-1	-1	-1	1	1	1
6	1	1	-1	1	1	-1	1	-1
7	-1	-1	-1	-1	1	-1	-1	-1
8	1	-1	-1	-1	1	1	1	-1
9	1	-1	-1	1	-1	1	-1	-1
10	-1	-1	-1	1	1	-1	1	1
11	1	1	1	-1	1	1	-1	-1
12	-1	1	-1	-1	1	1	1	1
13	-1	-1	-1	-1	-1	-1	-1	1
14	-1	-1	-1	1	-1	-1	1	-1
15	-1	1	1	1	1	-1	-1	1
16	1	1	1	-1	-1	1	-1	1
17	-1	-1	1	-1	-1	1	-1	-1
18	-1	-1	1	1	-1	1	1	1
19	-1	-1	1	1	1	1	1	-1
20	1	1	-1	1	-1	-1	1	1
21	1	1	-1	-1	1	-1	-1	1
22	1	1	1	1	1	1	1	1
23	-1	1	1	-1	-1	-1	1	1
24	-1	-1	1	-1	1	1	-1	1
25	1	-1	1	-1	1	-1	1	1
26	-1	1	1	-1	1	-1	1	-1
27	-1	1	-1	-1	-1	1	1	-1
28	-1	1	-1	1	-1	1	-1	1
29	1	-1	1	-1	-1	-1	1	-1
30	1	-1	1	1	1	-1	-1	-1
31	1	-1	1	1	-1	-1	-1	1
32	1	-1	-1	1	1	1	-1	1

RESULTS AND DISCUSSION

Effect of HPMC Concentration on Amylograph Viscosity

The effect of HPMC concentrations on amylograph characteristics is shown in Table 3. Amylograph curves made from rice flour on starch resemble those of other cereal starches, but appreciable differences are found among various rice varieties. According to Hallick and Kelly (1959), particle size, concentration, and other factors within a variety influence the size and shape of the amylograph curves. By holding those factors constant, the differences observed among amylograph curves could be attributed to the effect of HPMC substituted.

As mentioned earlier in the literature review, HPMC is a very important ingredient, because the fermentation gas can not be retained without it. In a solution state at lower temperatures, HPMC is hydrated and there is little polymer-polymer interaction other than simple entanglement (Sarkar 1979). Viscosity created by HPMC at 30° C may slow the rate of gas diffusion during dough fermentation. As the temperature was increased from 30° C, the HPMC molecules gradually lost their water of hydration, which was reflected by a slow drop in the relative viscosity (Fig. 1).

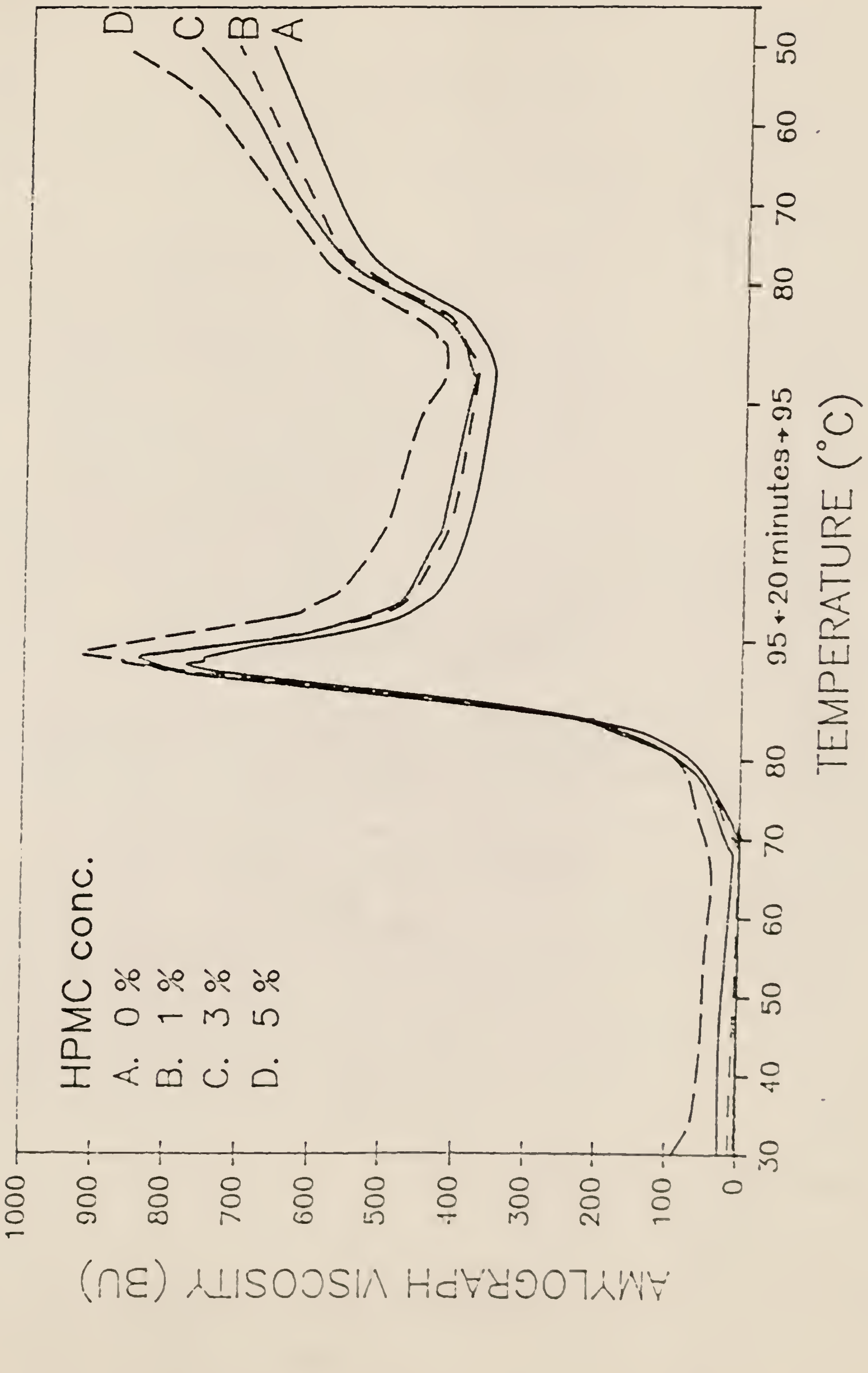
Table 3. Effect of HPMC concentrations on amylograph characteristics

HPMC conc.	Transition temp. (°C)	Temp.at peak (°C)	Viscosity (B.U.)		
			Peak	Cool to 50° C	Set back
0%(control)	68.2	92.4	755 a	668 a	-88 a
1%	67.6	92.5	835 b	715 b	-120 b
3%	66.5	92.9	840 b	770 c	-70 a
5%	66.6	93.2	910 c	875 d	-35 c

* Values are means of two replications.

* Means for each column with the same letter are not significantly different (P=0.05) by LSD method.

Fig. 1. Amylograph curves for rice flours containing 0%, 1%, 3%, and 5% HPMC.


HPMC conc.
A. 0 %
B. 1 %
C. 3 %
D. 5 %
A
B
C
D
AMYLOGRAPH VISCOSITY (BU)
0
100
200
300
400
500
600
700
800
900
1000
30
40
50
60
70
80
95←20 minutes→95
80
70
60
50
TEMPERATURE (°C)

The temperature at which the first perceptible increase in viscosity occurs, probably due to the combined effect of starch gelatinization in rice flour and gelation of HPMC, is called the temperature of transition. From the curves (Fig. 1) obtained from the amylograph, increasing amounts of HPMC added to rice flour slightly decreased the transition temperature, indicating that thermal gelation of HPMC took place at a lower temperature than the gelatinization of rice flour (Sarkar 1979).

Temperatures at peak for different treatments were slightly increased with increasing amounts of HPMC. Furthermore, increasing HPMC addition produced a recognizable increase change in maximum peak height (viscosity). The water absorption capacity of rice flour containing HPMC was observed to be considerably higher than that of rice flour only, which resulted in relatively lower amounts of water available for rice flour, as the amount of HPMC increased. The viscosity increase can also be explained by the phenomenon, a precipitation of molecules, that is observed for the HPMC suspensions when subjected to increasing temperature (Sarkar 1979). Those combined effects might have caused the increases in peak maximum viscosity. Therefore, HPMC has a function as a highly efficient thickener. Because of the high water-absorbing capacity of HPMC, it not only releases water necessary for starch gelatinization, but it also seems to be involved in the volume increase through water vaporization during baking.

After 20 min heating at 95° C , the paste was cooled down to 50° C. Increased HPMC concentrations showed significantly higher viscosity after cooling to 50° C. The difference in viscosity values between hot paste and paste cooled to 50°C is referred to as the set back value, and reflects the partial effect of HPMC concentrations as well as the retrogradation behavior of starch in the rice flour. The setback is caused by a decrease of energy in the system that allows more hydrogen bonding and thus increased viscosity. The differences in viscosity may relate to the degree of crumb firmness in the final breads during the storage periods.

Effects of Ingredients on Gas Production of Yeast

Effect of sugar. Sugar is one of the most common ingredients which can have an effect on gas production. The gas production of rice flours (3% yeast) with increasing levels (1-11%) of sucrose is shown in Fig. 2. The lowest gas production was observed in rice flour containing 1% sucrose. Rice flours containing 3% and 5% sucrose also gave significantly lower rates of gas production after 1.0 hr fermentation time, when compared to

Table 4. Gas production (in GU) of rice flour (3% yeast) with different levels of sugar

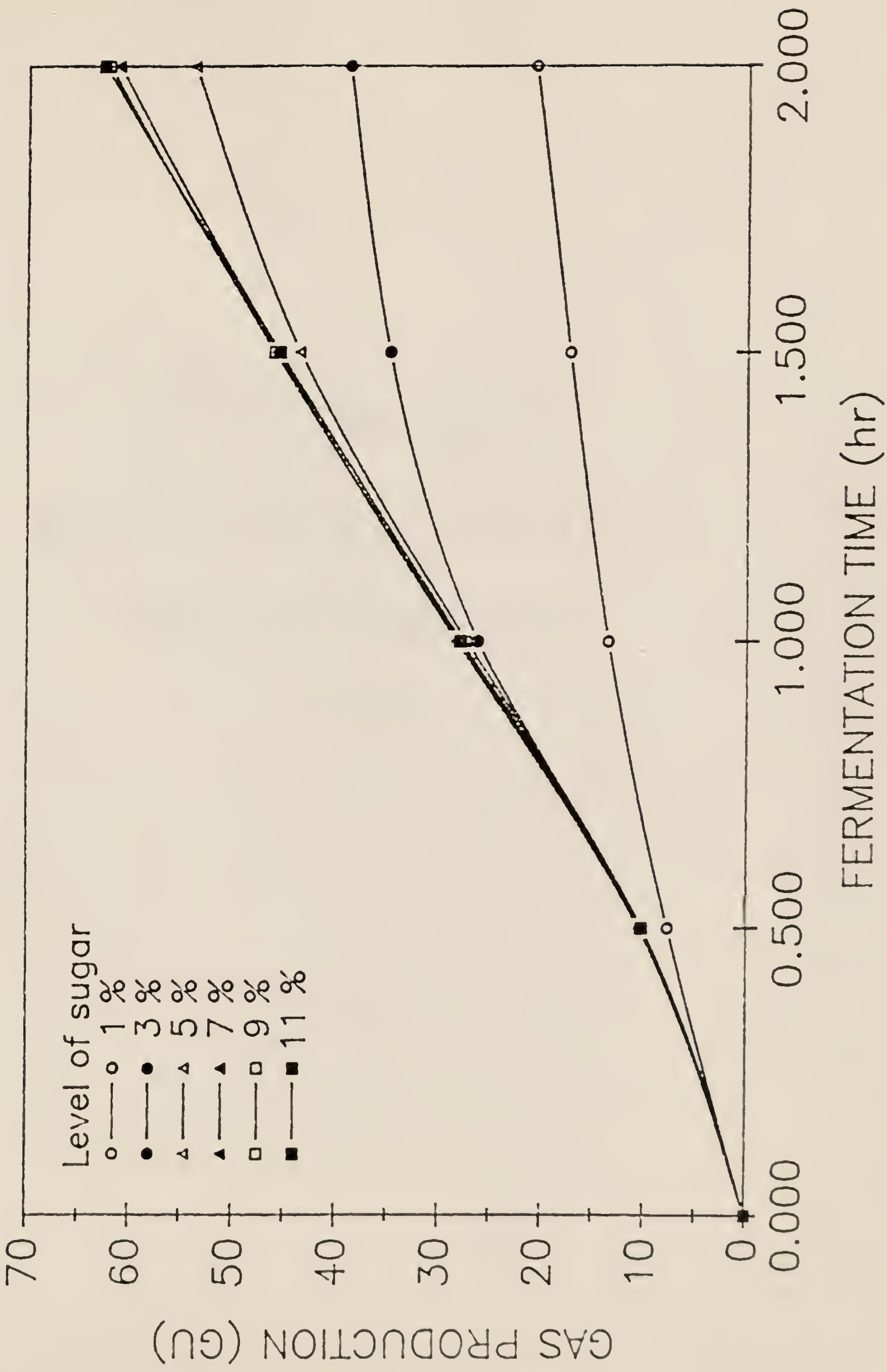
Sugar level (%)	Fermentation time (hr)			
	0.5	1.0	1.5	2.0
1	7.7 a	13.5 a	17.3 a	20.7 a
3	10.2 b	26.2 b	34.8 b	38.8 b
5	10.2 b	27.3 c	43.5 c	53.8 c
7	10.5 b	28.3 d	45.7 d	61.2 d
9	10.3 b	28.0 cd	46.0 d	62.2 de
11	10.2 b	27.8 cd	45.5 d	62.7 e

* GU = Gasograph Unit.

* Values are means of three replications.

* Means for each column with the same letter are not significantly different (P=0.05) by LSD method.

Fig. 2. Gasograph gas production of rice flour during 2 hr fermentation with 1, 3, 5, 7, 9, and 11% sugar and 3% yeast.


Level of sugar
1 %
3 %
5 %
7 %
9 %
11 %
GAS PRODUCTION (GU)
0
10
20
30
40
50
60
70
FERMENTATION TIME (hr)
0.000
0.500
1.000
1.500
2.000

rice flours containing 7-11% sucrose (Table 4).

Even though high levels of sucrose (9% and 11%) initially lowered the rate of gas production a little bit, increasing amounts of sucrose extended the period of high gas production, indicating that the sucrose was the first choice of yeast for fermentation and played an important role in delaying the effective period of maltose fermentation. Mogoffin and Hoseney (1974) reviewed that yeast didn't ferment all available sugars at the same rate or even at the same time, showing distinct preferences for the simpler, more readily fermentable sugars over the more complex sugars. Because of yeast's invertase enzyme, sucrose is converted almost immediately to glucose and fructose. Maltose, produced by amylase amd damaged starch, is not fermented appreciably when in the presence of fructose and glucose. If low levels of sucrose are added, therefore, the rate of gas production drops after sucrose exhaustion until yeast enzymes adapt to maltose.

The important thing to remember when evaluating the gas production curves is the total length of time over which a dough must produce gas in order to accomplish satisfactory rising during fermentation. Since fermentation time for a dough lasts 1.5 hr in the bread-making experiments, the amount of gas produced during this time is very critical for dough expansion. The optimum sugar levels for good gas production during the fermentation period were shown to be between 7-11%.

Effect of salt. Gas production of 3% yeast, sugarless rice slurries with varying levels of salt (0-5%) are shown in Fig. 3. Rice flour with no added salt yielded the lowest gas production, while rice flour containing 3% salt produced the largest amount of gas among treatments. The gas production values of slurries having 1 and 2% salt were significantly lower than the 3% salt slurry (Table 5). This may be because yeast is not only a very osmotolerant organism, but requires NaCl, to some extent, as a mineral source for its optimum activity. Ling and Hoseney (1977) also said that the aldolases of yeasts require Na^+ for activity.

However, under conditions of high osmotic pressure, yeast cells tend to become dehydrated, and it interferes with yeast metabolism. From Table 5, rice flour suspensions with over 3% salt progressively showed decreased gas production. Consequently, it was demonstrated that a high percentage of salt could retard the rate of yeast fermentation.

Effect of yeast. The effect of yeast concentrations on gas production is well depicted in Fig. 4. The degree of gas production was highly dependent on the amount of yeast present. When yeast content was varied from 1% to 5%, gas

Table 5. Gas production (in GU) of rice flour (3% yeast) with different levels of salt

Salt level (%)	Fermentation time (hr)			
	0.5	1.0	1.5	2.0
0	1.3 a	4.3 a	7.7 a	11.2 a
1	1.8 b	7.0 b	12.7 b	18.5 b
2	2.3 cd	8.2 c	15.2 c	20.8 c
3	2.7 d	8.7 d	15.7 d	21.7 d
4	2.2 bc	8.5 cd	15.2 c	21.0 c
5	2.0 bc	8.2 c	15.0 c	20.7 c

* GU = Gasograph Unit.

* Values are means of three replications.

* Means for each column with the same letter are not significantly different (P=0.05) by LSD method.

Fig. 3. Gasograph gas production of rice flour during 2 hr fermentation with 0, 1, 2, 3, 4, and 5% salt and 3% yeast.

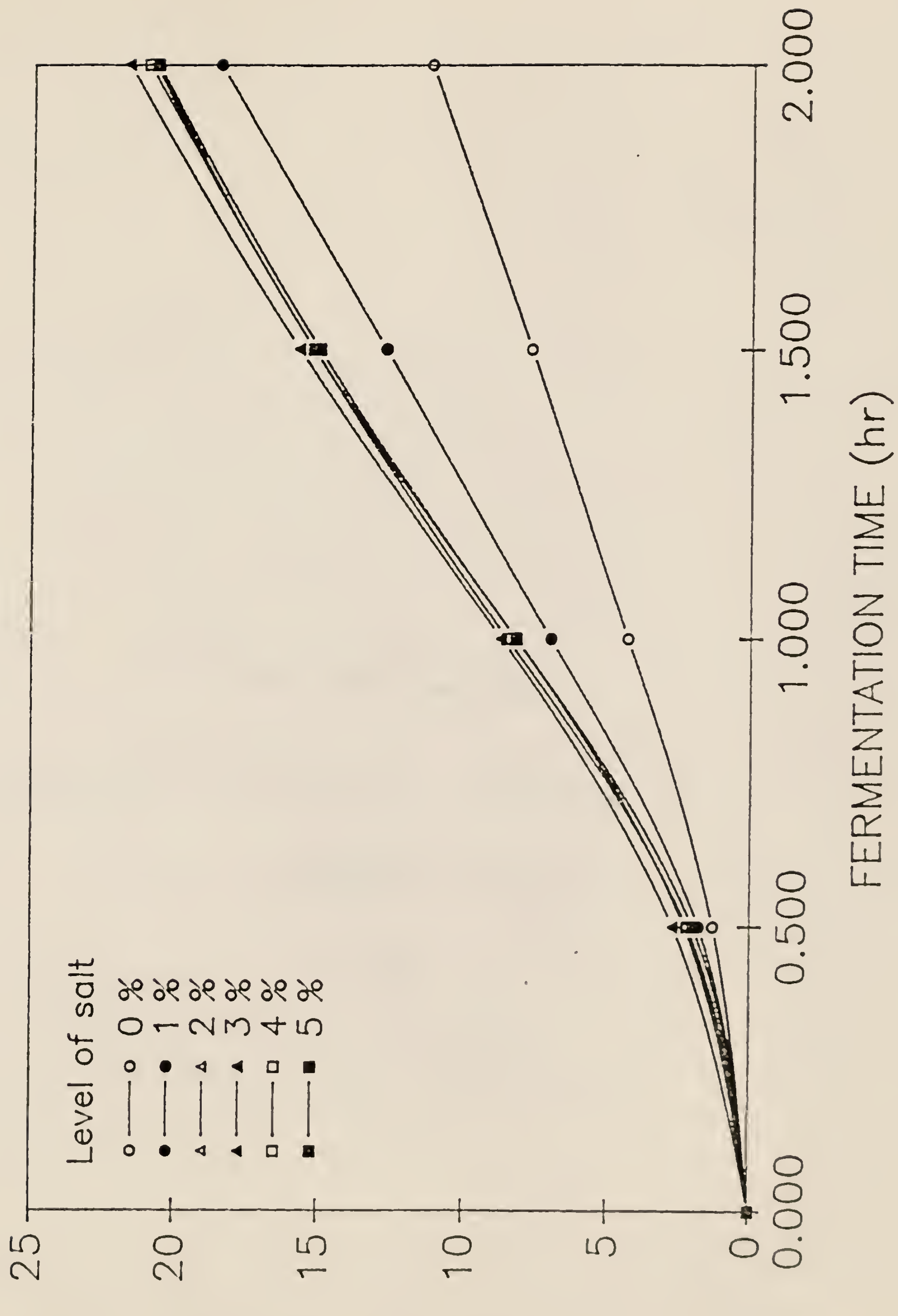

GAS PRODUCTION (GU)
0
5
10
15
20
25
FERMENTATION TIME (hr)
0.000
0.500
1.000
1.500
2.000
Level of salt
0 %
1 %
2 %
3 %
4 %
5 %

Table 6. Effect of yeast concentrations on gas production (in GU) of rice flour

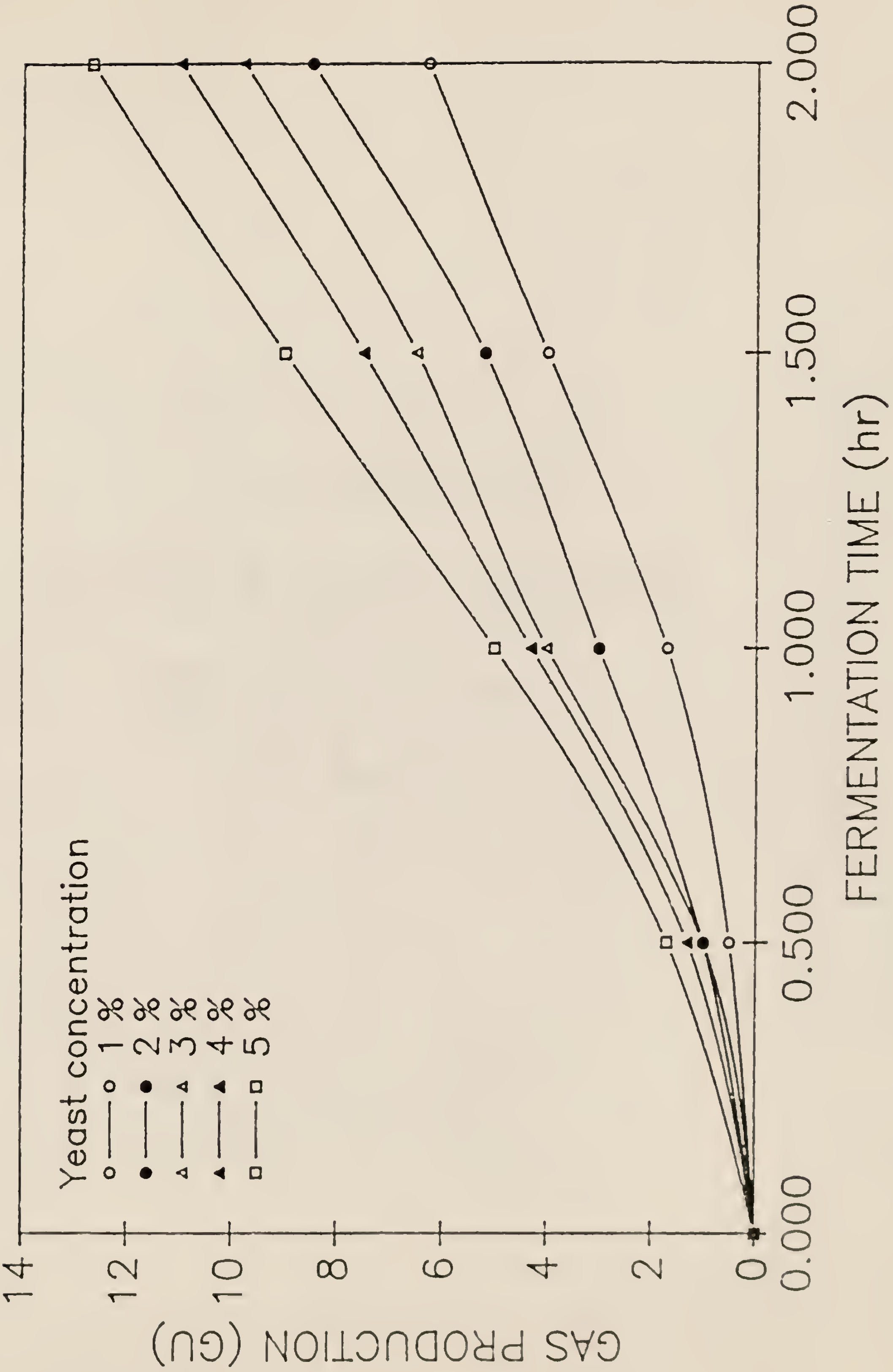
Yeast conc. (%)	Fermentation time (hr)			
	0.5	1.0	1.5	2.0
1	0.5 a	1.7 a	4.0 a	6.3 a
2	1.0 b	3.0 b	5.2 b	8.5 b
3	1.0 b	4.0 c	6.5 c	9.8 c
4	1.3 c	4.3 d	7.5 d	11.0 d
5	1.7 d	5.0 e	9.0 e	12.7 e

* GU = Gasograph Unit.

* Values are means of three replications.

* Means for each column with the same letter are not significantly different (P=0.05) by LSD method.

Fig. 4. Gasograph gas production of rice flour during 2 hr fermentation with 1, 2, 3, 4, and 5% yeast.


GAS PRODUCTION (GU)
0
2
4
6
8
10
12
14
FERMENTATION TIME (hr)
0.000
0.500
1.000
1.500
2.000
Yeast concentration
1 %
2 %
3 %
4 %
5 %

production varied from 6.3 GU to 12.7 GU at 2 hr fermentation time. Throughout the whole fermentation time, increasing yeast content obviously increased the gas production of rice flour (Table 6). Even though high concentrations of yeast gave high gas production, consideration should be made to choose an optimum concentration that would ensure sufficiently vigorous gassing rate within a selected fermentation time. Selecting too high a concentration of yeast could cause premature expansion of rice flour doughs.

Combined effects of yeast, salt, and sugar. To determine the combined effect of yeast, salt, and sugar, two levels of yeast (2% and 3%), and two levels of salt (1.5% and 2.5%) were chosen with three sugar levels, i.e., 3%, 5%, and 7% (Table 7). Gas production curves for nine ingredient combinations are shown in Fig. 5. Like the effect of sugar levels for rice flour containing 3% yeast without salt, increasing amounts (3-7%) of sucrose increased the gas production after 1.0 hr. The increase in gas production was more profound late in fermentation time than early in fermentation.

Yeast level was, of course, a critical factor affecting the gas production. When the two different levels (2% and 3%) of yeast were compared by keeping the salt level constant (2.5%), there was a significant

Table 7. Combined effects of yeast, salt and sugar on gas production (in GU) of rice flour

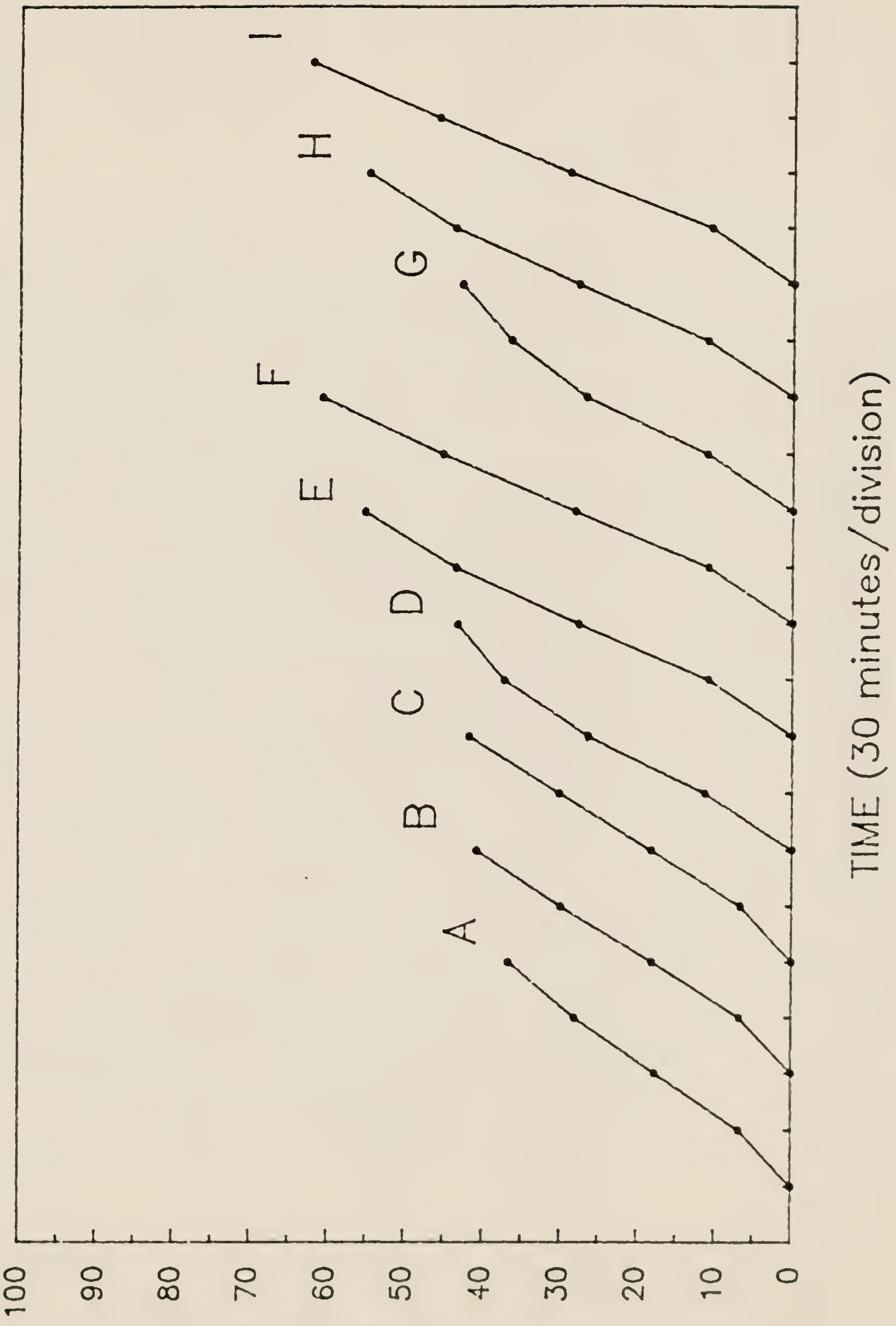
Yeast:salt:sugar (%)	Fermentation time (hr)			
	0.5	1.0	1.5	2.0
(A) 2:2.5:3	6.8 a	17.8 a	28.2 a	36.7 a
(B) 2:2.5:5	6.8 a	18.2 a	30.0 ab	40.8 b
(C) 2:2.5:7	6.7 a	18.3 a	30.2 b	41.8 bc
(D) 3:2.5:3	11.5 b	26.5 b	37.3 c	43.3 c
(E) 3:2.5:5	11.0 b	27.7 bcd	43.5 d	55.2 d
(F) 3:2.5:7	11.0 b	28.2 cd	45.2 de	60.8 e
(G) 3:1.5:3	11.2 b	26.8 bc	36.5 c	42.8 c
(H) 3:1.5:5	11.2 b	27.8 bcd	43.7 d	54.8 d
(I) 3:1.5:7	10.7 b	29.0 d	45.8 e	62.2 e

* GU = Gasograph Unit.

* Values are means of three replications.

* Means for each column with the same letter are not significantly different ($p=0.05$) by LSD method.

Fig. 5. Combined effects of yeast, salt and sugar on gasograph gas production of rice flour (refer to the table for A - I).


GAS PRODUCTION (GU)
0
10
20
30
40
50
60
70
80
90
100
TIME (30 minutes/division)
A
B
C
D
E
F
G
H
I

(p=0.001) difference in gas production between the two yeast levels. The difference in gas production between the levels of salt (2.5% and 1.5%) was not significant (p=0.5109), which suggested that the salt levels combined with sugar and yeast seemed not to affect the ratio of gas production. Interaction among yeast, salt, and sugar was also analyzed. The difference in gas production among three sugar levels was not statistically different for both the two yeast and two salt levels.

Effect of HPMC. The formulas for determining the effect of HPMC concentrations on gas production used 10 g (14% m.b.) rice flour, 0.7 g sucrose, 0.2 g NaCl, and 0.3 g yeast. When rice flour and sugar were omitted from the formula, the gas production was almost zero (less than 0.5 GU in 2 hr fermentation). The HPMC was not enzymatically hydrolyzed. Nevertheless, formulas containing HPMC (1, 3, and 5%) gave significantly higher gas production, compared to that without HPMC (Table 8). This result agrees with the suggestion that a gum absorbs large amounts of water and forms a gel-like medium which holds all ingredients in suspension, and thus facilitates uniform gas production (Bruinsma and Finney 1982). Apparently 3% HPMC was sufficient to maintain a uniform distribution of yeast. However, 5% HPMC bound so much water that free water available for yeast was limiting, leading to a slightly

Table 8. Effect of HPMC levels on gas production (in GU) of rice flour

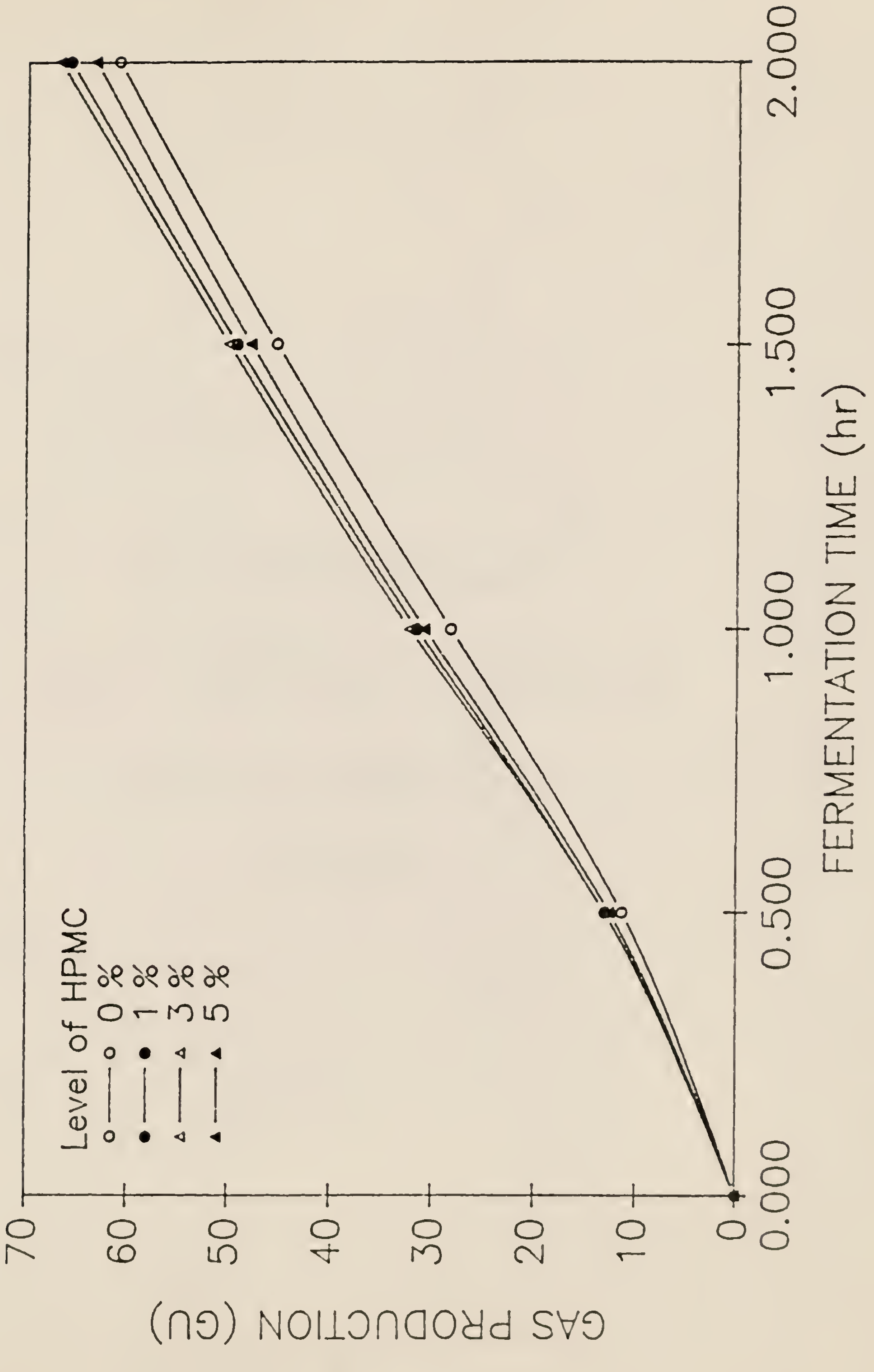
HPMC (%)	Fermentation time (hr)			
	0.5	1.0	1.5	2.0
0	11.3 a	28.2 a	45.3 a	61.0 a
1	13.0 b	31.5 b	49.2 b	65.8 b
3	13.0 b	32.2 b	50.0 b	66.8 b
5	12.5 b	30.7 b	47.8 c	63.3 c

* GU = Gasograph Unit.

* Values are means of three replications.

* Means for each column with the same letter are not significantly different (P=0.05) by LSD method.

Fig. 6. Gasograph gas production of rice flour during 2 hr fermentation with increasing concentrations of HPMC.


Level of HPMC
0 %
1 %
3 %
5 %
GAS PRODUCTION (GU)
0
10
20
30
40
50
60
70
FERMENTATION TIME (hr)
0.000
0.500
1.000
1.500
2.000

decreased gas production.

Screening Experiment

One-eighth fractional replicate of 2^8 factorial design was conducted for the screening experiment. The data obtained from the 32 observations is given in Appendix 3. Loaf volume is one of the most important factors evaluating the quality of breads. This is especially true for rice bread, because good retention of fermentation gas is the key to success in rice bread making. Therefore, evaluation of rice-bread quality was basically focused on loaf volume in this screening stage. Loaf volume varied widely from 220 cc to 960 cc (average volume was 446 cc).

Table 9 shows the analysis of variance table for the screening experiment. Each variable effect was interpreted as the average change in the response as the variable was changed from its low level to its high level. The largest effect on volume was due to HPMC ($p=0.0076$) which meant that as HPMC was increased from a low level of 1% to a high level of 5%, the increase in volume was the largest among ingredients tested (Table 10).

The second largest effect on volume was attributed to soy flour. Substituting 6% soy flour significantly ($P=0.016$) decreased the loaf volume of rice bread (Table

Table 9. ANOVA for the screening experiment

Source	df	SS	F	PR>F
Salt	1	10731.125	0.75	0.4498
Sugar	1	49141.125	3.44	0.1606
HPMC	1	593505.125	41.56 ***	0.0076
Oil	1	49928.000	3.50	0.1583
Water	1	45904.500	3.21	0.1709
Yeast	1	45150.125	3.16	0.1735
Oxidant	1	8450.000	0.59	0.4978
Soy	1	347778.000	24.35 **	0.0160
Salt*sugar	1	1740.500	0.12	0.7501
Salt*HPMC	1	8844.500	0.62	0.4887
Salt*oil	1	13861.125	0.97	0.3972
Salt*water	1	3741.125	0.26	0.6441
Salt*yeast	1	23544.500	1.65	0.2893
Salt*oxidant	1	21.125	0.00	0.9717
Salt*soy	1	3570.125	0.25	0.6515
Sugar*HPMC	0	0.000	.	.
Sugar*oil	0	0.000	.	.
Sugar*water	1	13366.125	0.94	0.4047
Sugar*yeast	0	0.000	.	.
Sugar*oxidant	0	0.000	.	.
Sugar*soy	1	23653.125	1.66	0.2884
HPMC*oil	1	30135.125	2.11	0.2423
HPMC*water	1	41905.125	2.93	0.1852
HPMC*yeast	0	0.000	.	.
HPMC*oxidant	1	7021.125	0.49	0.5337
HPMC*soy	1	232903.125	16.31 **	0.0273
Oil*water	1	3042.000	0.21	0.6758
Oil*yeast	0	0.000	.	.
Oil*oxidant	0	0.000	.	.
Oil*soy	1	9112.500	0.64	0.4828
Water*yeast	1	24976.125	1.75	0.2778
Water*oxidant	1	3120.500	0.22	0.6720
Water*soy	1	6050.000	0.42	0.5615
Yeast*oxidant	0	0.000	.	.
Yeast*soy	1	21321.125	1.49	0.3090
Oxidant*soy	1	3042.000	0.21	0.6758

* Interaction between two ingredients.

** Significant at 0.05 level.

*** Significant at 0.01 level.

Table 10. T - tests (LSD) for loaf volume

Ingredients	Level code	Means	
Salt	1	463.94	a
	-1	427.31	a
Sugar	1	484.81	b
	-1	406.44	b
HPMC	1	581.81	c
	-1	309.44	d
Oil	1	485.13	e
	-1	406.13	e
Water	1	483.50	f
	-1	407.75	f
Yeast	1	483.19	g
	-1	408.06	g
Oxidant	1	461.88	h
	-1	429.38	h
Soy flour	1	341.38	i
	-1	549.88	j

* Alpha = 0.05 df = 3 MSE = 14280.8
Critical value of t = 3.18245
Least significant difference (LSD) = 134.46

* Means with the same letter for each ingredient are not significantly different.

9). In addition to single effects, there was a significant (p=0.0273) interaction effect between HPMC and soy flour as well. The loaf volume in breads without soy flour was increased dramatically from 1% HPMC to 5% HPMC, while the loaf volume with 6% soy flour was increased very slowly (Table 11).

Salt had very little effect on bread volume. It is generally used at about 1-2%, based on the flour weight. Bread made with no salt is quite flat and tasteless. Two percent salt appeared to be the optimum, because more gave a salty taste. Dough containing 12% sugar produced a relatively higher volume than that containing 4% sugar, simply because more gas was produced. It was previously demonstrated that higher levels of sugar (7-11%) maintained the rapid rate of gas production during dough fermentation. Sugars that remain unfermented appear as residual sugars in the finished bread, where they exert significant effects on product quality. Accordingly, higher sugar concentrations are commonly used for their marked improvement in loaf volume, crust color, flavor and keeping quality.

The crust color of breads having high (12%) sucrose was brown or golden brown, a characteristic of good bread quality. On the other hand, the crust color of low (4%) sucrose breads was golden or light golden. It was estimated that 10% sucrose was an appropriate level for producing a good quality bread in terms of volume, color,

Table 11. Interaction between HPMC and soy flour on the volume of rice bread

Level code		VOLUME LSMEAN (cc)
HPMC	Soy flour	
1	1	392.250 a
1	-1	771.375 b
-1	1	290.500 a
-1	-1	328.375 a

* Means with the same letter are not significantly different (P=0.05) by LSD method.

taste and grain.

HPMC, without doubt, had the most critical effect on the bread volume. Doughs made from rice flour are very weak when compared to those made from wheat flour. Then how could a rice flour dough containing HPMC retain gas? This is an important question that must be answered before rice bread making can be completely understood. According to Hoseney (1984), gas retention is only an application of the simple law of diffusion. The rate of diffusion varies, depending on some characteristic of doughs. He concluded that something about the structure of the gluten protein resulted in a slow rate of diffusion. Therefore, HPMC as a gluten substitute in a rice flour dough may play a major role in slowing the rate of carbon dioxide diffusion in the dough by providing appropriate viscosity.

The volume of the breads having 8% corn oil was slightly higher than that of the breads containing 4% oil, even though the volume difference was not significant. Generally, bread containing fat in the formula stays soft and more palatable for a longer period of time than does bread prepared without fat. The effect of oil was found in the bread texture. The rice breads containing high oil content produced a softer and more tender crumb (result not shown here). One tsp. of oil was also used to coat the dough surface for the purpose of easy handling. Since the amount of oil coating the dough was not constant, the actual oil content present in the dough could possibly be under- or overestimated.

The mean volume of the breads with high water (100%) content was considerably higher than that of the breads with low water (90%) content. However, this difference was not shown to be significant. The lack of statistical significance was not easily understood since water absorption was greatly affected by the amount of HPMC and soy flour in a formula.

Very little difference (no significance) in the loaf volume was observed between breads with and without potassium bromate. The mean loaf volume (461.88 cc) of the breads treated with 60 ppm potassium bromate was just a little bit higher than that (429.38 cc) of the breads made without the oxidant. According to Sullivan et al. (1963), it can be assumed that removal of the thiol (-SH) groups in soluble proteins by oxidation lessens the weakening effect of thiol groups on the disulfide bonds of dough matrix. Thiol groups, mainly from cysteine, of rice soluble proteins might have readily reacted with the oxidant.

The major protein-body protein in cereals is prolamine, and glutelin is the matrix protein. But, despite its low prolamine content, rice protein is 80% glutelin and is mainly protein-body protein with little matrix protein (Juliano 1985). Because it had very little matrix protein, oxidation was not necessarily effective in improving bread volume by strengthening the dough's rheological properties.

Determination of Soy Flour Substitution Level

As a result of the screening experiment, HPMC and soy flour appeared to be the most critical control factors. For the further study of a formula optimization of rice bread with soy flour, a maximum level of soy flour substitution had to be found which would not seriously affect loaf volume. Otherwise, great differences in volume response caused by a wide range of soy flour level might cause difficulties in evaluating data. Levels of other ingredients except soy flour and HPMC were fixed (2% salt, 10% sugar, 6% oil, 3% yeast, and 95% water), based on the previous instrumental and screening studies.

As shown in Fig. 7, adding soy flour (3-6%) had a tremendously adverse effect on the bread volume. This agreed with the studies indicating that lowered loaf volume of soy flour-containing doughs was at least partly explained by impaired gas retention capacity. Increasing levels of HPMC, to some extent, counteracted the loaf volume-depressing effect of soy flour.

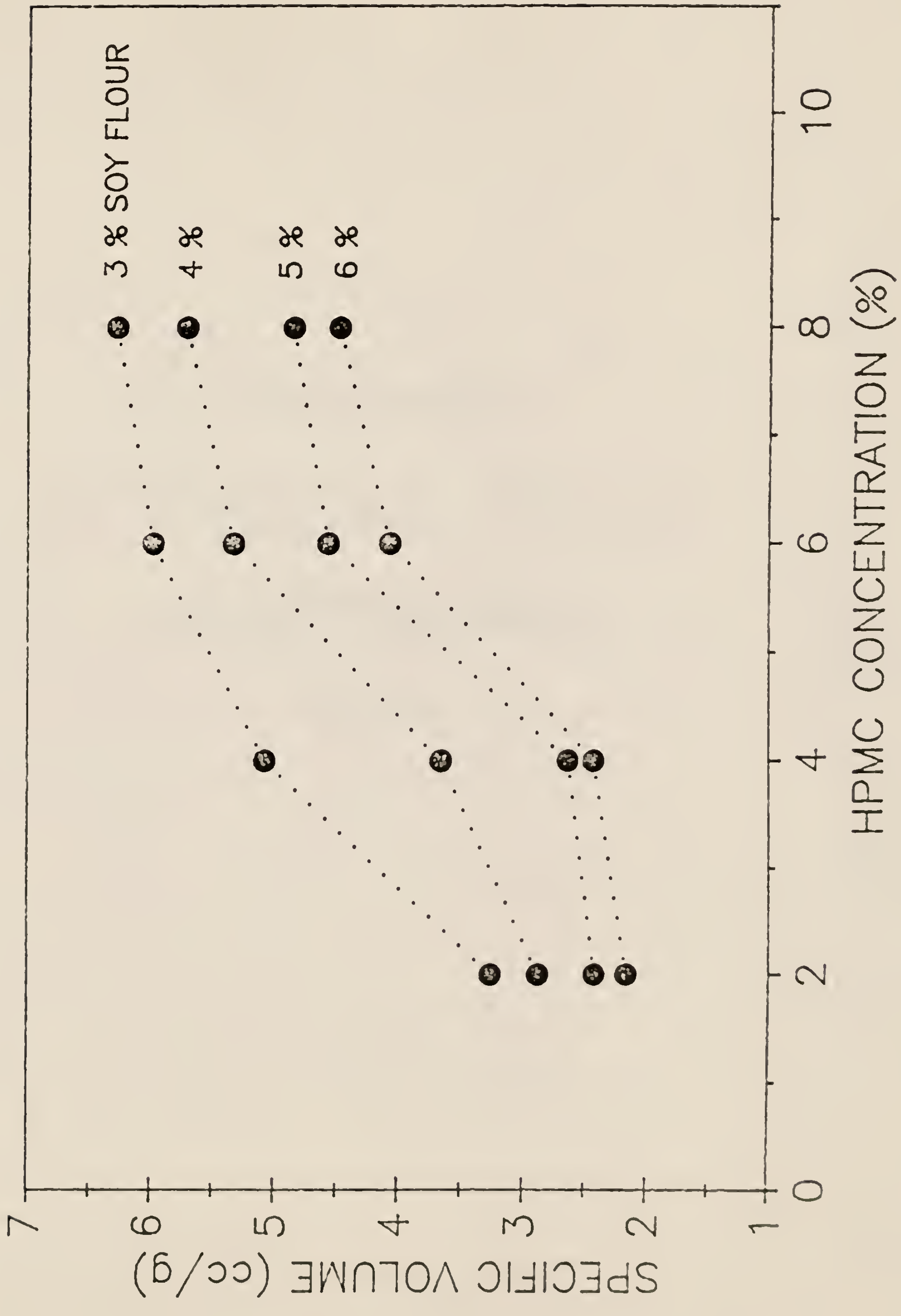
Without doubt, 3% soy flour substitution produced the biggest loaf volume among the different levels of soy flour

Table 12. Effect of HPMC conc. on specific vol. of rice bread with soy flour substitution (3%-6%)

HPMC conc.(%)	Soy flour substitution			
	3 %	4 %	5 %	6 %
2	3.26	2.88	2.42	2.16
4	5.08	3.66	2.64	2.43
6	5.98	5.33	4.57	4.07
8	6.28	5.71	4.85	4.48

* One loaf per sample

Fig. 7. Effect of soy flour substitution level with increasing HPMC concentration on specific volume of rice bread.


SPECIFIC VOLUME (cc/g)
1
2
3
4
5
6
7
HPMC CONCENTRATION (%)
0
2
4
6
8
10
3 % SOY FLOUR
4 %
5 %
6 %

substitution. Despite an advantage of big loaf volume, it had an unacceptable problem, called "keyholing", which is the shrinking of the bread sidewalls to give the breads a keyhole shape. Because of weakness in crumb structure, breads having more than about 5.0 specific volume exhibited the keyhole shape.

The breads containing both 5% and 6% substitution of soy flour gave relatively low loaf volume, unless they contained a large amount of HPMC, which resulted in quite difficult dough handling. 4% soy flour substitution was thought to be the maximum level that could be used without seriously depressing loaf volume. Loaf volume was also dependent on the amount of HPMC present in the formula. A HPMC range between 4 and 6% seemed to be appropriate for producing good volume, and a relatively easily handled dough.

Formula Optimization for Rice Bread with 4% Soy Flour Substitution

For the purpose of optimizing the formula for rice flour bread containing 4% soy flour, an RSM (Response Surface Methodology) design was conducted. According to the previous screening experiment, HPMC and soy flour were found to be the two critical variables. However, determination of the optimum soy flour level (4%) preceded the formula optimization, because the formula optimization was not concentrated on rice bread itself, but rice bread with an appropriate amount of soy flour which had already been established.

Instead, water was considered a critical factor. Even though water content did not appear to significantly influence the bread volume, it was still thought to be one of the important factors affecting overall quality of rice bread. Optimum water absorption might be greatly affected by the amount of HPMC and soy flour added. Therefore, a final decision was made to optimize the soy flour substituted rice bread, testing HPMC and water as the variables for the RSM experiment. The optimization pattern of two variables at five levels (Table 13) required 13 runs and was replicated twice (total of 26 runs). The results for the RSM experiment are given in Table 14 and Table 15.

For the formula optimization, the full response surface model is as shown in the following.

$$Y = BO + B1X1 + B2X2 + B11X1^2 + B22X2^2 + B12X1X2$$

where: Y = dependent variable (response)

X1, X2 = independent variables

Dependent variables such as specific volume and grain score were used as a input data and the regression coefficients were solved by using the above regression equations which also predict the effects of any combination

Table 13. Variables and their levels for RSM design

Ingredient variables	Level code				
	-2	-1	0	1	2
HPMC (%)	3.0	3.5	4.5	5.5	6.0
Water (%)	92.0	93.0	95.0	97.0	98.0

* fixed ingredients; 100% flour (rice:soy = 96:4), 2% salt, 10% sugar, 6% oil, and 3% yeast.

Table 14. Effect of variables on specific volume

Randomized Run #	Controlled Variable		Specific Volume (cc/g)	
	HPMC	Water	Actual	Predicted
1	-1	-1	2.33	2.75
2	-2	0	2.40	2.21
3	0	-2	3.76	3.09
4	1	1	5.51	4.96
5	2	0	4.31	4.50
6	0	0	3.94	3.78
7	0	0	3.50	3.78
8	0	0	3.69	3.78
9	0	2	3.86	4.11
10	-1	1	2.92	2.74
11	1	-1	3.37	3.59
12	0	0	3.80	3.78
13	0	0	3.58	3.78

* Values are averages of two replications.

* Coefficient of determination (R^2) = 0.834. Coefficient of multiple correlation = 0.913. Standard error of estimate = 0.366.

Table 15. Effect of variables on grain score

Randomized Run #	Controlled Variable		Grain Score	
	HPMC	Water	Actual	Predicted
1	-1	-1	3.0	3.51
2	-2	0	2.5	1.50
3	0	-2	6.5	6.09
4	1	1	6.0	6.15
5	2	1	6.5	6.79
6	0	0	5.5	5.65
7	0	0	5.0	5.65
8	0	0	6.0	5.65
9	0	2	6.0	4.77
10	-1	1	1.5	2.74
11	1	-1	7.5	7.15
12	0	0	6.0	5.65
13	0	0	5.0	5.65

* Values are averages of two replications.

* Coefficient of determination (R^2) = 0.758. Coefficient of multiple correlation = 0.871. Standard error of estimate = 1.004.

of independent variables not actually tested on the values of dependent variables.

Results of RSM method are graphically illustrated in the form of contour plots. Contour maps for specific volume and grain score responses, are given for all levels of HPMC and water within ranges (Fig. 8 and Fig. 9).

The response surface for specific volume was found to be :

Specfic volume = -129.2741 + 3.254372 (water) - 13.91245 (HPMC) + 0.1723586 (water*HPMC) - 0.02031741 (water squared) - 0.1885789 (HPMC squared).

The contour plot of specific volume (Fig. 8) indicated that the highest specific volume was obtained with the extreme highest values for both water and HPMC levels within ranges. The response surface for grain score was also found to be:

Grain Score = -219.7032 + 4.388109 (water) + 10.39725 (HPMC) - 0.02771619 (water*HPMC) - 0.02359622 (water squared) - 0.6666113 (HPMC squared).

As shown in Fig. 9, the grain score increased toward the upper left corner of the plot, suggesting that increasing the HPMC levels had a markedly inproving effect on grain score.

After completion of Response Surface Plots, an Overlapping Plot was generated to identify the regions where optimum quality for both responses would be met.

Fig. 8. Contour plot of specific volume (A = 2.5, B = 3.5, C = 4.5, D = 5.5) for water and HPMC levels.

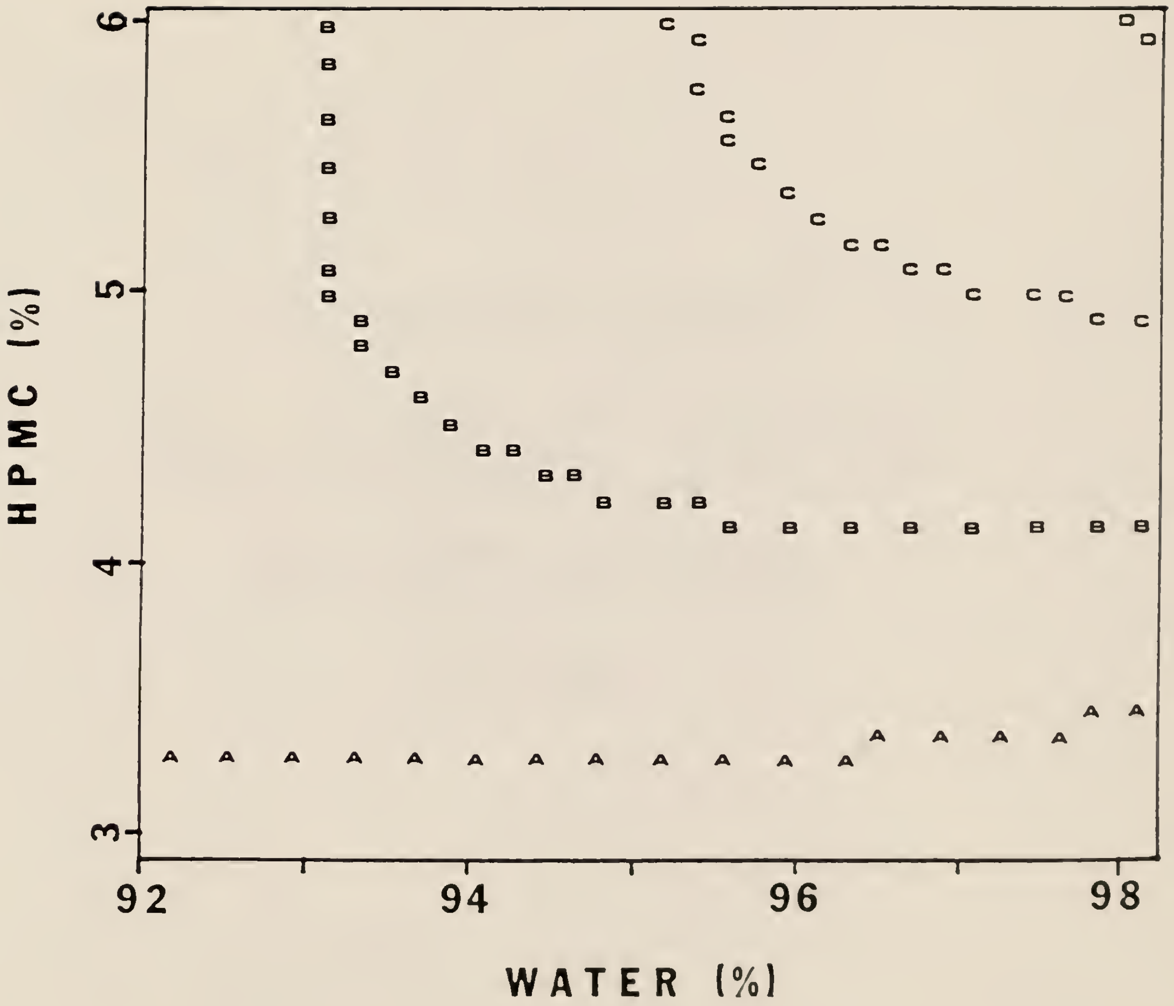
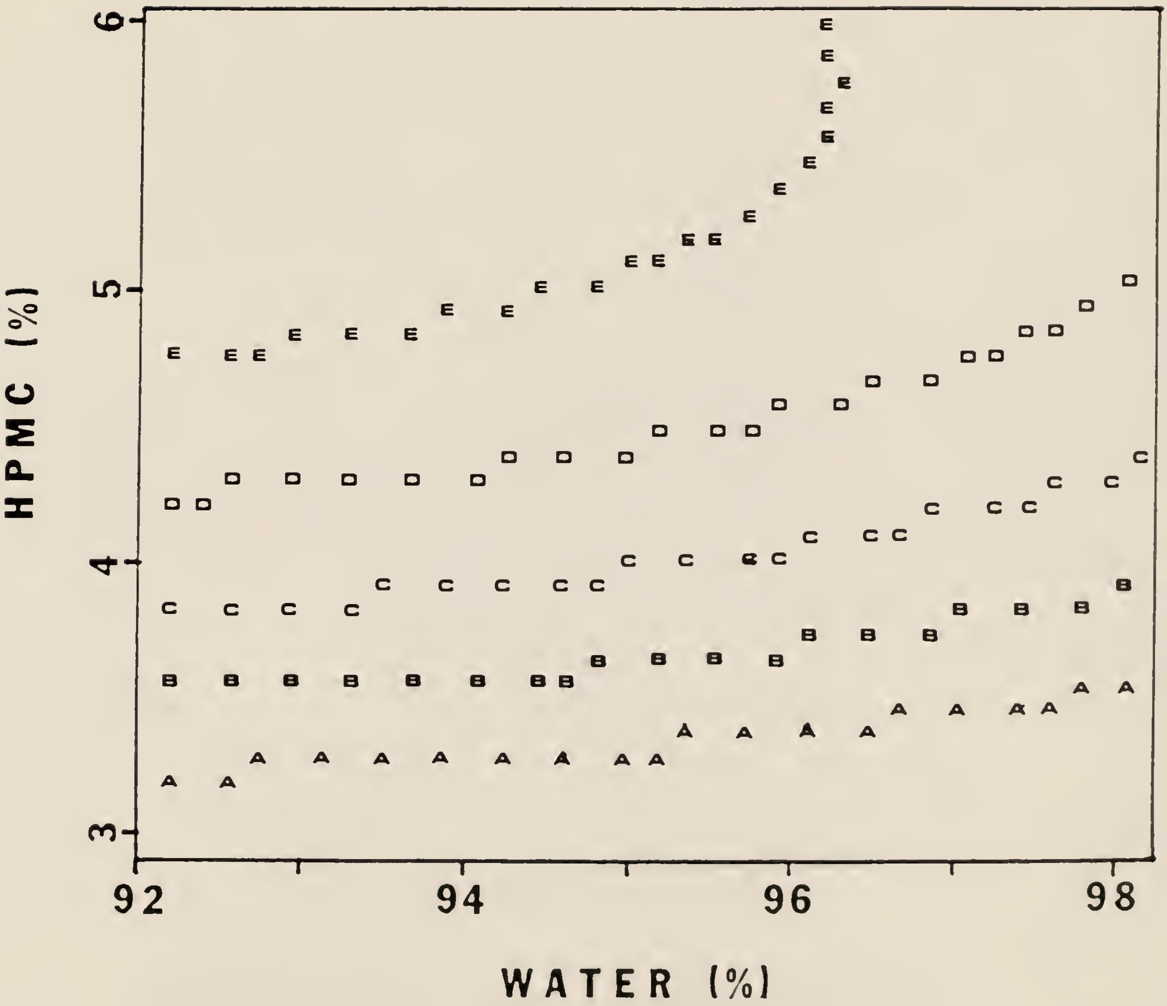

HPMC (%)
3
4
5
6
92
94
96
98
WATER (%)
A
B
C
D

Fig. 9. Contour plot of grain score (A = 2.5, B = 3.5, C = 4.5, D = 5.5, E = 6.5) for water and HPMC levels.


HPMC (%)
6
5
4
3
92
94
96
98
WATER (%)
A
B
C
D
E

Optimum criteria for both responses were as follows: specific volume between 4.0 and 4.5 and grain score greater than 6.5. In Fig. 10. an overlapping region for both responses would be ideal for optimum quality of rice bread.

Five points (Fig. 10) in the overlapping region were chosen for a confirmative test to confirm the predictions made by the RSM analysis. The result (Appendix 4) was closely related to the prediction values. Finally, it was recommended that the optimum levels of HPMC and water were 5.7% and 94.5%, respectively. Table 16 gives the optimum formula of rice bread with soy flour substitution.

A baking test was conducted using the optimized formula (Table 16) to determine the reproducibility of rice bread baking procedure (Table 17). Due to the high variability (standard deviation of 0.27), the reproducibility of this procedure seemed to be relatively lower compared to that of the regular pup-loaf test using wheat flour. The specific volume of rice breads are probably affected by a number of processing variables as well as ingredient variables. The high sensitivity of rice bread to unfavorable or unstable processing conditions such as required hand manipulation of the dough, and incomplete mixing action caused by the sticky property of rice doughs might have resulted in the high variability. Therefore, it is recommended that the effects of different processing variables should be studied under stable

Fig. 10. Overlapping plot of specific volume and grain score for water and HPMC levels (X = Points for confirmative test).

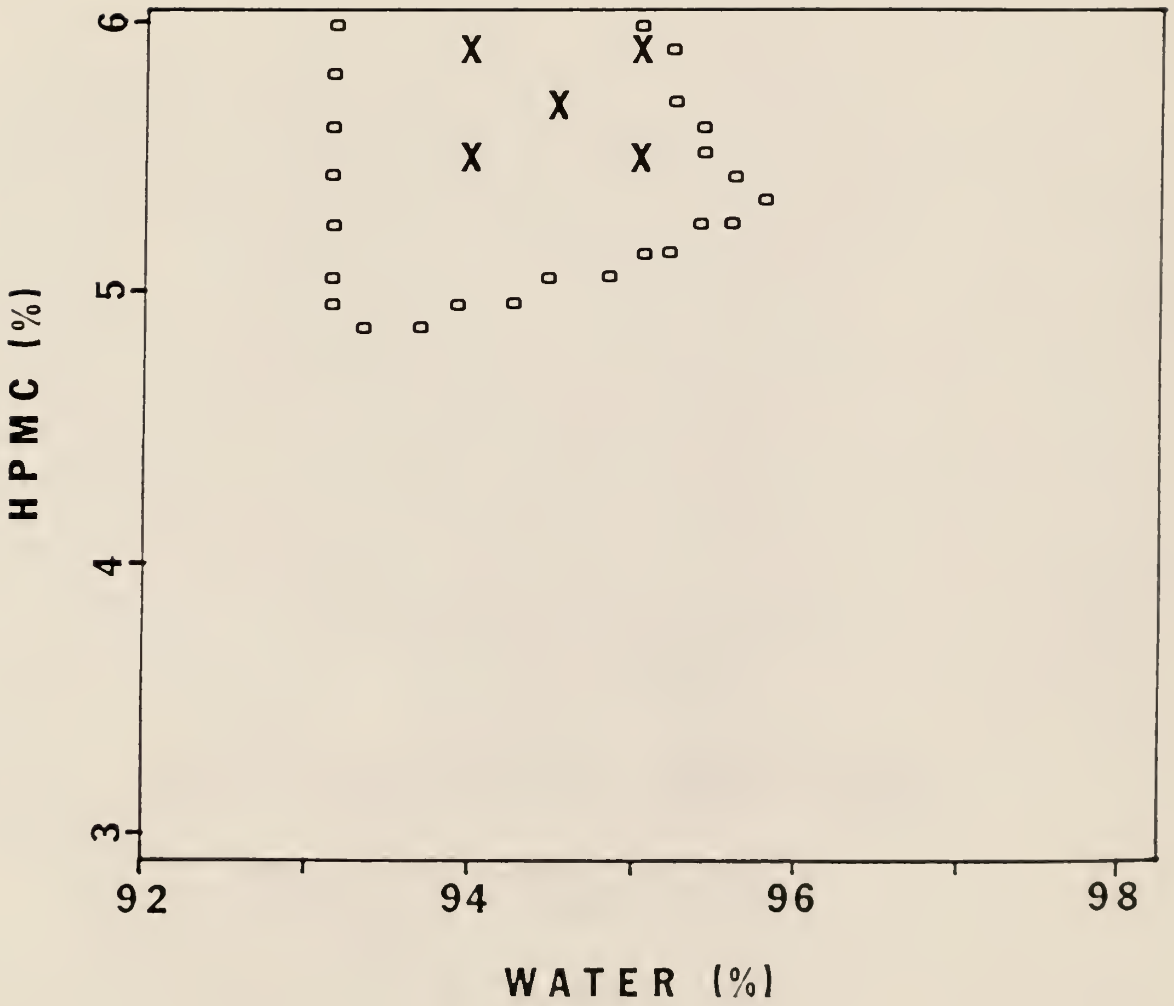

6
5
4
3
HPMC (%)
92
94
96
98
WATER (%)
X
X
X
X
X

Table 16. Optimum formula of rice bread with soy flour substitution

Ingredients	%
Rice flour	96.0
Soy flour	4.0
Salt	2.0
Sugar	10.0
HPMC	5.7
Oil	6.0
Water	94.5
Yeast	3.0

Table 17. Specific volume of optimized rice bread containing soy flour

Run #	Specific vol. (cc/g)
1	4.16
2	4.88
3	4.45
4	4.07
5	4.28
6	4.20
7	4.77
8	4.28
9	4.14
10	4.37

$\bar{X} = 4.36$

$s = 0.27$

$n = 10$

processing conditions as a future project. Breads made from rice flour by the optimized formula are shown in Fig. 11 and 12.

Fig. 11. Whole-loaf breads made from rice flour

Left: 100% rice flour (control)

Right: 4% soy flour substitution.


4% SOY
RICE BREAD
CONTROL

Fig. 12. Sliced breads made from rice flour

Left: 100% rice flour (control)

Right: 4% soy flour substitution.


CONTROL
RICE BREAD
4% SOY

CONCLUSIONS

Since a yeast-leavened rice bread is suitable for people allergic to wheat proteins, close examination of each individual ingredient on the quality of the rice bread was necessary for improved bread production.

In rice bread making, HPMC has been an essential ingredient to retain gas produced during yeast fermentation. From the amylograph curves, it was shown that HPMC provided the rice dough with appropriate viscosity necessary to retard the diffusion of gas, ultimately retaining the gas in the dough.

Gas production is a basic function of yeast, as is the gas retaining property of dough. Besides the essential ingredients (flour, yeast, and water) for fermentation of rice dough, other ingredients such as sugar, salt, and HPMC have shown to affect the rate of gas production.

Gas production, to a large extent, was dependent on the concentration of yeast present in the rice dough. Throughout the whole fermentation period, increasing yeast content significantly increased gas production of rice flour. Increasing sugar levels was highly associated with high gas production. Two different levels of salt, however, did not make any difference in gas production.

For the baking test, experimental work was divided into two stages, a screening experiment by fractional factorial design, and formula optimization of rice bread with soy flour substitution by RSM design. Special attention was given to the addition of an oxidant (potassium bromate) and to soy flour substitution.

The results of the screening experiment showed that a significantly positive effect on loaf volume was due to HPMC, and a significatly negative effect was attributed to soy flour. There was a significant interaction effect between HPMC and soy flour. Very little difference in loaf volume was observed between breads with and without potassium bromate, indicating that the oxidant did not contribute heavily to the improvement of bread volume.

In spite of the detrimental effect of soy flour on bread volume, it was partially substituted for rice flour for the purpose of improving nutritioanal values of rice bread. Increasing the levels of HPMC, to a degree, counteracted the loaf volume-depressing effect of soy flour. Soy flour could be successfully substituted for rice flour at levels up to 4%.

Finally, the RSM study suggested that the 4% soy flour could be used to make rice bread with good volume and grain, as indicated by the overlapping contour plot regions. As a result of confirmative test, the recommended levels of HPMC and water were 5.7% and 94.5%, respectively. The optimized formulation for rice bread with soy flour substitution was: flour 100% (96% rice flour and 4% soy flour), salt 2%, sugar 10%, HPMC 5.7%, oil 8%, water 94.5%, and yeast 3%.

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APPENDIX

Appendix 1. Composition of brown and white rice

	Brown rice	White rice
Moisture (%)	12.0	12.0
Kcal (100 g)	360	363
Protein (%)	7.5	6.7
Fat (%)	1.9	0.4
Ash (%)	1.2	0.5
CHO (total %)	77.4	80.4
Fiber (%)	0.9	0.3
Calcium (mg/100g)	32	24
Phosphorous (mg/100g)	221	94
Iron (mg/100g)	1.6	0.8
Sodium (mg/100g)	9	5
Potassium (mg/100g)	214	92
Thiamin (mg/100g)	0.34	0.07
Riboflavin (mg/100g)	0.05	0.03
Niacin (mg/100g)	4.7	1.6

Source: Kennedy 1980

Appendix 2. Basic formula for yeast leavened rice bread

Ingredients	Control 100 % Rice Bread (%)
[a]Rice flour	100.0
Salt	2.0
Sugar	7.5
[b]Methylcellulose	3.0
[c]Oil	6.0
Water	88.0
[d]Yeast	3.0

a. Riviana Rice Flour RM-100

b. Methocel K4M Premium Hydroxypropyl Methylcellulose

c. Wesson corn oil

d. Saf-Instant yeast

Appendix 3. Result of screening experiment

Run #	Vol.(cc)	Wt.(g)	Specific vol(cc/g)
1	908	138	6.58
2	637	144	4.42
3	333	118	2.82
4	320	146	2.19
5	252	138	1.83
6	312	141	2.21
7	292	147	1.99
8	325	143	2.27
9	445	141	3.16
10	270	149	1.81
11	960	139	6.91
12	425	143	2.97
13	227	140	1.62
14	273	143	1.91
15	558	146	3.82
16	222	154	1.44
17	648	144	4.50
18	222	153	1.45
19	960	132	7.27
20	303	148	2.05
21	237	145	1.63
22	822	141	5.83
23	380	151	2.52
24	272	149	1.83
25	265	151	1.75
26	698	140	4.99
27	327	141	2.32
28	315	143	2.20
29	648	143	4.53
30	712	141	5.05
31	397	150	2.65
32	295	141	2.09

Appendix 4. Result of confirmative baking test

HPMC:Water (%)	Specific vol.		Grain score	
	Actual	Predicted	Actual	Predicted
5.5:94.0	3.69	4.00	6	6.97
5.5:95.0	4.27	4.36	7	6.75
5.7:94.5	4.51	4.24	7	6.93
5.9:94.0	4.42	4.06	7	7.05
5.9:95.0	4.36	4.49	6	6.82

EFFECTS OF INGREDIENT VARIABLES AND FORMULA OPTIMIZATION FOR RICE BREAD WITH SOY FLOUR SUBSTITUTION

by

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AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

Effects of ingredients (salt, sugar, HPMC, oil, water, yeast, potassium bromate, and soy flour) on the quality of a yeast-leavened rice bread were studied for improved bread production. Hydroxypropyl methylcellulose (HPMC) has been an essential ingredient to retain gas produced during yeast fermentation. From the amylograph curves obtained by the amylograph, it was suggested that HPMC provided the rice dough with appropriate viscosity necessary to retard the diffusion of gas. Gas production is a basic function of yeast. Sugar, salt, and HPMC have shown to affect the rate of gas production determined by the gasograph.

The experimental work for baking test was divided into two stages, screening experiment by a two-level fractional factorial design and formula optimization of rice bread containing soy flour by RSM (Response Surface Methodology) design. The results of the screening experiment showed that a significantly positive effect on loaf volume was due to HPMC, and a significantly negative effect to soy flour. Very little difference in loaf volume was observed between breads with and without potassium bromate, indicating that the oxidant did not function well on the improvement of bread volume. Increasing the levels of HPMC somewhat

counteracted the loaf volume-depressing effect of soy flour. Soy flour could be successfully substituted for rice flour at levels up to 4%.

Finally, the RSM study suggested that 4% soy flour containing rice bread with good volume and grain could be obtained with the region in the overlapping contour plot. The optimized formulation for rice bread with soy flour substitution was recommended as followings: flour 100% (96% rice flour and 4% soy flour), salt 2%, sugar 10%, HPMC 5.7%, oil 8%, water 94.5%, and yeast 3%.