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FLAVOR INTERACTIONS OF SOY AND POTASSIUM CHLORIDE IN MORTON™ LITE SALT® MIXTURE IN WHITE PAN BREAD

by

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INTRODUCTION

For centuries, man has placed a high value on salt. "Salt of the earth" and "worth his salt" reflect the importance he assigns to this mineral. While it is known that sodium (Na) is essential for the normal functioning of the human body, the exact amount required has not been determined. The estimated safe and adequate levels of dietary intake for Na have been set at 250-270 mg for infants 6-12 months of age, 600-1800 mg for children 7-10 years of age and 1150-3300 mg for adults (Committee on Dietary Allowances, Food and Nutrition Board 1980). Despite the low requirement for Na, the total daily intake of sodium chloride (NaCl) in the U.S. is estimated at 10,000-12,000 mg (3,900-4,700 mg Na) per day (Dahl 1972), an amount far in excess of estimated needs.

In humans, the appetite for salt is acquired primarily as a result of social and dietary custom and probably has no relationship to requirement. Morino and Langford (1978) reported that the threshold of salt taste is dependent upon current salt intake. When dietary salt intake is low, salt excretion in saliva decreases, causing the taste buds to become more sensitive. Thus, foods previously perceived as bland are perceived as salty. When dietary salt intake increases, adaptation readily occurs. Similarly, Dahl (1958) reported that patients on Na restricted diets, (2500 mg NaCl per day), recognized increased saltiness when only 1000 mg NaCl was added to their daily intake. The addition of 5000 or 10,000 mg NaCl to the diets of the same individuals with a daily intake of 10,000-20,000 mg NaCl went unnoticed.

The relationship between Na and hypertension is an issue of increasing concern in the U.S. It is estimated that 16-20% of the American white population over the age of 50 suffers from hypertension (Boyle 1970). The percentage increases to 40% among black Americans. While a causal relationship has not been established, there is considerable evidence that individuals with essential hypertension experience a decrease in blood pressure when Na intake is restricted to less than 1000 mg per day and blood pressure rises again when substantial amounts of Na are reintroduced to the diet (Dahl 1961). Weber and Laragh (1978) estimated that approximately one-third of all individuals with hypertension are Na sensitive and respond to a reduced Na intake. Na restriction early in life may offer protection against hypertension in this "at risk" group (Dahl 1972, American Academy of Pediatrics 1974, Morgan et al 1978). The Food and Nutrition Board of the National Academy of Science recommended that the amount of Na in infant foods be reduced (NAS/NRC 1979). Similarly, the Committee on Nutrition of the American Academy of Pediatrics has advocated the reduction of salt intake by children (American Academy of Pediatrics 1974).

Normotensive individuals do not show a similar sensitivity to Na. The case for Na restriction for the general population is supported, however, by epidemiological studies of primitive societies. Dahl (1961) observed that primitive societies consuming relatively small amounts of Na (1400-1800 mg daily) exhibited relatively little hypertension and little or no increase in blood pressure with age. When migration or occulteration occurred, the incidence of hypertension rose (Maddocks 1967, Freis 1976).

Darby (1980) summarized the current research as follows: "Recent information concerning dietary salt intake justifies the following conclusions: (1) the estimates of per capita intake of salt in the U.S., while clearly above the minimal physiologic need, are within the range of physiologic accommodation by the healthy individual; (2) acute, grossly excessive or low levels of salt intake can be toxic; (3) general, moderate reduction in dietary salt intake cannot predictably be anticipated to decrease the development of hypertension; (4) some individuals with hypertension, however, do benefit from limitation of Na intake at levels appropriate to the therapeutic regimen advised by their physician; and (5) the role of the diet in the cause of prevention of hypertension has not yet been defined."

Despite the absence of decisive evidence of a causal relationship between salt intake and hypertension, increasing numbers of consumers are restricting their Na intake and exerting pressure on the food industry to reduce the use of Na-containing ingredients in food processing. Efforts to reduce present levels of dietary Na include the use of potassium chloride (KCl) and NaCl mixtures as salt substitutes. However, KCl imparts a bitter flavor and astringent mouthfeel to some foods. Kulp et al (1982) reported that Morton Lite Salt® mixture, a 1:1 blend of NaCl and KCl, contributed atypical flavor notes to white pan bread. Similar findings were reported by Salovaara (1982a). The findings of Salovaara and Kulp's group suggested the need for additional studies of the effectiveness of formulation changes to mask undesirable KCl flavors in white pan breads.

Preliminary work for this study indicated a seemingly more intense KCl bitterness when soy oil was used as compared to either cottonseed or corn oil in a bread formulation with the Lite Salt® mixture. This is particularly important in light of the present trend of using soy oil, soy-whey blends and soy-containing dough conditioners in commercially prepared bread (Dubois 1980). The objectives of this study were (1) to evaluate the physical and sensory characteristics of white pan bread containing Morton Lite Salt® mixture and (2) to determine if an interaction of soy and KCl rather than KCl itself were responsible for atypical flavor notes in yeast breads.

REVIEW OF LITERATURE

Potassium Chloride as a Replacement for Sodium Chloride

Effects on Health. The use of NaCl/KCl mixtures as a NaCl substitute lowers dietary Na intake while increasing dietary potassium (K) within nontoxic levels. In a study of NaCl/KCl mixtures, Frank and Mickelson (1969) reported that replacement of the estimated daily average 5000 mg of NaCl added to the diet in cooking with a 1:1 mixture of NaCl/KCl reduced Na intake from 4100 mg to 3100 mg and increased K intake from 4600 mg to 5900 mg.

The ameliorating effects of K long have been recognized. As early as 1928, Addison suggested the use of K salts to lower blood pressure in the treatment of hypertension. In a study of the possible relationship between the development of hypertension and NaCl/KCl ratio, Priddle (1962) evaluated 101 of his patients suffering from hypertension. He reported that increased levels of dietary K resulted in a fall in blood pressure beyond that attributable to Na restriction. Animal studies have shown that K has a similar protective effect against the development of hypertension in rats fed a high Na diet (Dahl 1972, Meneely and Battarbee 1976, Battarbee et al 1979).

Young et al (1976) reported that K has a diuretic effect on the kidney and increases Na excretion. In addition, an increase in dietary K aids in replenishing K loss resulting from the use of thiazide diuretics in the treatment of hypertension (Frank and Mickelson 1969, Cummins and Fisher 1975). An increase in dietary K is compatible, then, with the treatment of hypertension.

Use in Processed Foods. Wyatt (1981) reported that green beans and corn could be processed with a 1:1 $NaCl/KCl$ mixture without loss of salt flavor or desirability. A panel of 40 untrained judges chosen on the basis of availability rated corn and green beans processed with 2.3% salt mixture too salty and therefore less desirable. Both vegetables with 1:1 $NaCl/KCl$ mixture at the 1.7% level were rated equally desirable to a reference processed with 1.5% $NaCl$. The basis for determining desirability was not given and bitterness, per se, was not evaluated.

Seman et al (1980) investigated the effect of partial replacement of Na with nine different combinations of $NaCl$, KCl and magnesium chloride ($MgCl_2$) at high and low ionic strengths (0.42 and 0.21) and low ionic strength (0.13%) potassium phosphate on bologna. A panel of 127 untrained judges evaluated samples on a 5 point scale from "extremely like" to "extremely dislike" for flavor, texture, color and bitterness. They concluded that since high ionic strength $NaCl$ and 1:1 $NaCl/KCl$ mixtures were rated equally acceptable, salt mixtures in bologna would yield a product acceptable to consumers.

Effects on Flavor. KCl, while contributing its own saltiness to foods, also imparts a disagreeable bitter flavor. $NaCl$ appears to mask this bitter flavor, and for this reason, mixtures of $NaCl$ and KCl often are used as $NaCl$ substitutes.

In a study of $NaCl/KCl$ mixtures, Frank and Mickelson (1969) reported that 67% of 72 panelists reported a 0.064% KCl solution as tasting bitter. When 0.1% $NaCl$ was added, only 11% evaluated the solution as bitter. To evaluate the effect of increasing proportions of KCl in $NaCl/KCl$ mixtures in cooking and table use, Frank and Mickelson calculated the amount of each of six salt mixtures having various proportions of $NaCl$ and KCl used by 10 panelists over a 5 day period. They reported that panelists salted their foods with essentially the same amounts of regular table salt as with 1:1 mixtures.

Kincaid et al (1975) concluded that the degree of saltiness of Morton Lite Salt® mixture was similar to that of table salt. A 15 member sensory panel, 18 to 26 years in age, found that a 1.2% concentration of Lite Salt® tasted as salty as a 1% NaCl solution. Replacement of table salt with Morton Lite Salt® mixture represented a 41% reduction in dietary Na. Similarly in a study of Na and K intakes of male subjects, Mickelson et al (1977) reported that 1:1 mixtures represented a 44% reduction of Na and that there was no tendency to increase the use of the 1:1 mixture to compensate for reduced Na intake.

Wyatt and Ronan (1982) evaluated the effect of NaCl/KCl salt mixtures in bread made with white flour and a mixture of white flour and what was described as wheat flour. An untrained panel of 40 judges was selected on the basis of availability. Using a hedonic scale, the panel rated breads containing 1% (flour weight) 1:1 salt mixture as not significantly different from the NaCl-containing breads. While the validity of sensory evaluation by a small number of judges using a hedonic scale is questionable, the Wyatt study suggests that salt mixtures at the 1% level produce more acceptable breads than at the 2% replacement level. It should be noted, however, that 1.5% salt is needed in commercial bread production, and 2% is most commonly used in white pan bread (Bruinsma 1983).

In a similar study by Salovaara (1982b) 5, 11, 20 and 40% of the NaCl (2% flour weight) was replaced with equivalent amounts of KCl. A panel of 12-15 experienced judges evaluated breads during two tasting sessions per day with each session 1½ hours in duration. Triangle testing indicated that flavor and aroma of breads containing KCl at the 20% replacement level did not differ from that of breads containing NaCl. However, a significant off-flavor described as bitter, sour, and musty at the 40% replacement level was reported. Breads rated acceptable in the Wyatt study (1% salt at 50% replacement) had similar KCl content to breads rated acceptable in the Salovaara report (2% salt with 20% replacement).

In contrast, sensory studies by Kulp et al (1982) characterized breads containing Morton Lite Salt® mixture as having questionable consumer acceptability. A five member panel experienced in bread profiling evaluated white pan breads made with 1.5% and 2.2% levels of KCl, Morton Lite Salt® and NaCl. The panel reported that the Lite-containing breads had atypical flavor profiles at both the 1.5% and 2.2% levels. Bitter taste was prevalent in both flavor and aftertaste of crumb and crust. KCl tongue feel also was perceived. These atypical flavor notes decreased in intensity with aging but were detectable on day 4 in both bread and toast.

NaCl and NaCl/KCl Mixtures in Breadmaking

Functions of NaCl in Breadmaking. NaCl performs three principle functions in bread. First, it contributes flavor characteristics. Without NaCl, bread flavor has been described as flat, insipid or bland and generally has poor consumer acceptance. Niman (1981) stated, "Salt contributes its own unique flavor and accentuates the flavor of other bread components and fermentation by-products." Secondly, salt controls fermentation by reducing yeast activity, thereby decreasing gas production. Uncontrolled fermentation results in undesirable variation in loaf volume, crumb grain and texture. Finally, NaCl has a strengthening effect on gluten attributed to its role in gluten aggregation. In a review of chemical bonding in dough, Wehrli and Pomeranz (1969) indicated that theoretically, ions may enhance both association and dissociation of dough components. Since the addition of NaCl to dough increases elasticity and reduces extensibility, they concluded that salt enhances assocation. Danno and Hoseney (1982) found an increase in mixing time and in width and height of the mixograph curve as NaCl concentration was increased. In addition, NaCl influences dough stability. Dough mixed beyond the point of minimum mobility maintained greater resistance to extension when salt was included (Sanchez et al 1973).

Effects of NaCl/KCl Salt Mixtures on Various Parameters and Breadmaking. In a comprehensive study of Morton Lite Salt® mixture, Kulp et al (1982) compared dough rheology, baking properties and flavor of breads containing NaCl, KCl and Lite Salt® at 2 and 4% replacement levels. No significant differences were found between the effect of NaCl and Lite Salt® on starch pasting, specific volume or crumb firmness. The time required to reach minimum mobility, however, was shorter in doughs containing Lite Salt® than in doughs containing NaCl, and gassing power studies indicated that Lite Salt® inhibited yeast growth much less than NaCl, thus decreasing proof time.

Salovaara (1982b) investigated the rheological properties of dough when 20, 40, or 100% (2% flour weight basis) NaCl was replaced with an equivalent amount of KCl, $MgCl_2$, calcium chloride ($CaCl_2$), magnesium acetate, magnesium sulfate or sodium sulfate. Farinograph, extensigraph and rotation viscometer indicated that at replacement levels of 20%, $MgCl_2$ and $CaCl_2$ weakened physical properties of dough, magnesium and sodium sulfate strengthened them and KCl or magnesium acetate had no significant effect on dough rheology. Salovaara concurred with Lorenz et al (1971) and Kulp et al (1982) when he stated, "No essential technological problems are likely to be met when as much as 40% of NaCl normally present in bread is replaced with equivalent amounts of KCl. . . ."

Soy Products in Breadmaking

Effects on Bread Volume, Crumb Grain and Flavor. Soy flour was used initially in the early 1940's as a protein-rich additive. However, fortification of breads with soy flour at levels greater than 6-8% was found to adversely affect bread volume, crumb and flavor, necessitating alterations in bread formulations and breadmaking procedures.

Bohn and Favor (1945) attributed poor loaf volume in soy-fortified breads to both the dilution effect upon gluten concentration by the soy flour as well as to a lack of sufficient gas retention. They suggested oxidizing agents could improve dough properties. Similarly, Finney (1946) showed that bread containing 8% soy flour had excellent loaf volume and crumb grain when potassium bromate ($KBrO_3$) levels were increased in accordance with the amount of soy used. Tsen et al (1971) suggested 1.7 ppm $KBrO_3$ for each 1% soy flour and reported optimum baking performance was achieved with 10 to 15 ppm bromate in breads containing 12% soy flour.

Several additives minimize changes in bread quality resulting from the presence of soy flour. Calcium and sodium stearoyl-2-lactylate (CSL and SSL respectively) have been found to provide adequate loaf volume and crumb structure in soy-fortified bread. Tsen et al (1971) reported that breads fortified with 12 to 28% flour exhibited small loaf volumes and poor crumb. When 0.5% SSL was added, acceptable bread was produced with up to 24% soy flour. SSL was found to be more effective than CSL. Finney and Shogren (1971) and Fellers et al (1976) reported similar findings. Glycolipids also have been found to improve volume and grain of soy-containing breads (Pomeranz et al 1969a, 1969b; Shogren et al 1980). The mechanism by which a surfactant makes foreign proteins compatible is not fully understood. Tsen et al (1971) and Hoseney et al (1970) suggested that SSL and CSL formed a complex with gluten to strengthen the gluten network thus enabling the dough to accommodate soy flour or other protein additives.

Early sensory studies indicated soy flour at levels below 4% in breads had no undesirable effect on flavor (Finney et al 1950, Ofelt et al 1952). At increased concentrations, however, the soy flour imparted an undesirable beany flavor, related to flavor reversion. These objectionable flavors usually associated with enzyme-active flours have been eliminated with effective heat treatment and chemical modification (Pollack and Geddes 1960, Paulson and Horan 1965, Turro 1968). In a more recent sensory study of soy-fortified buns, Tsen et al (1976) reported that the soy-fortified bun flavor did not differ significantly in flavor ($P \leq 0.05$) from wheat buns and were rated acceptable by 85% of the 50 children involved in the study.

<u>Soy Products Currently Used in Breadmaking</u>. During the past decade, soy products have gained increasing acceptance by the baking industry for the partial or complete replacement of milk powders. Hoover (1979) stated that soy flour provided better water absorption and as good a tenderizing effect, body and resilience as nonfat milk solids (NFDM). In a study comparing the effects of various soy products to those of NFDM on bread

quality, Turro (1968) reported the addition of 3% (flour weight) processed soy protein product produced breads with crumb, loaf volume and texture similar to the control containing NFDM and the soy product had no beany flavor or aroma. In 1973, Turro and Sipos reported on a soy product which could be used alone or with whey solids. That product included additives which improved buffering and mixing properties, provided greater water absorption capacity and increased protein content over those of NFDM in bakery products. "Normal" loaf volume, grain and flavor also were reported.

The ability of soy flour to improve tenderness of cakes and bread has been attributed to its water holding capacity (Turro and Sipos 1970). Bohn and Favor (1945) reported that breads containing 5% soy flour were more compressible than control breads without soy and had a slower rate of staling. Steller and Bailey (1937) and Ying and Geddes (1948) reported similar results using soy flour at 3 and 5% replacement levels.

The baking industry now uses a wide range of soy products in the form of flour, milk replacers, dough conditioners and oils. The United States Standards of Identity for enriched white bread allows up to 3% soy flour. No appreciable change in absorption, mix and oxidant requirements have been evident at this level (Hoover 1979).

MATERIALS AND METHODS

Ingredients and Preparation

Bread samples were prepared at the experimental bake laboratory at Grain Marketing Research Center. Ingredients were obtained in quantities sufficient for the entire four week study.

The flour selected for the study was a composite of many hard wheat varieties harvested throughout the Great Plains of the United States in 1979. Moisture (13%) and protein content (11.7%; N × 5.7, 14% moisture basis) were determined by AACC approved methods 44-15A (1975) and 46-11 (1976), respectively (AACC 1976). Assessment of protein quality of the flour was made with a National Manufacturing Company mixograph (Appendix, Figure A-1). Optimum mixing time (four min) and optimum volume 930-950 cc) for this flour were determined in preliminary work. Optimum dough development and bread volume were achieved with 50 ppm ascorbic acid.

Concentrations of oil, dough conditioner and milk replacer were selected according to manufacturers' recommendations and to reflect levels currently used in commercially prepared baked products (Dubois 1980). Dough conditioners and milk replacers were specially formulated or selected for this study so that the composition of each was as similar to its counterpart as possible, but differing by its soy or non-soy constituent (Appendix, Table A-I). Eight treatment combinations were prepared, each with NaCl and Morton Lite Salt® mixture for a total of 16 treatments (Appendix, Table A-II).

On the day preceding each bake, flour, milk replacer and dough conditioner for each loaf were weighed and stored in individual airtight cannisters. Solutions of yeast, malt, salt and sugar were prepared on the day of each bake (Appendix, Table A-III). These solutions, as well as the oil, were pipetted into each dough immediately prior to mixing.

Breads were prepared according to a straight dough method on a three minute breadmaking schedule using the formulation given in Table I. Using two National Manufacturing 100 g dough mixers, each dough was mixed 4.25 min (the time required to reach minimum mobility), and fermented in a National Manufacturing Company fermentation cabinet for 90 min at 30°C and 76% relative humidity. The first punch (National sheeter) time was 52 min, second punch 25 min later and panning time (Thomson-Heart moulder) after an additional 13 min. Proof time was 34 min, the time required to proof controls to 7.9 cm. Samples were baked at 204°C for 24 min in a National Manufacturing Company reel-type electric oven. Immediately after baking, loaf volume was determined by rapeseed displacement. When breads had cooled to room temperature, loaf grains were evaluated as satisfactory, questionable or unsatisfactory. Breads were labelled, placed in plastic bags and stored at -8°F in a Hotpoint walk-in freezer for four weeks before sensory evaluation and six weeks before additional physical measurements were performed. Triangle tests during preliminary work indicated freezing for the four to six week period resulted in no detectable flavor differences.

Physical Measurements of Breads

Breads were kept frozen for six weeks until the Instron Universal Testing Machine (IUTM), model no. 1122, became available. Crumb compressibility of three 50 × 50 × 25 mm samples from the mid-section of each loaf were evaluated. The 50 cm^2 compression anvil, A372-17 was used with the 10 kg load cell at a crosshead speed of 100 mm per min. The upper

TABLE I

White Pan Bread Formula

Ingredient	Manufacturer	Weight, g
Flour	Regional Baking Standard 79[a] United States Grain Marketing Research Laboratory 1515 College Avenue Manhattan, KS 66502	100 (14% mb)
Yeast	1:1 blend Fleischmann:Busch Anheuser-Busch Inc. 1 Busch Place St. Louis, MO 63118 Nabisco Brands, Inc. Fleischmann Division P.O. Box 488 Sumner, WA	5.1-5.5
Sugar	C & H Pure Cane Sugar California and Hawaiian Sugar Co. San Francisco, CA 94106	6
Malt	Ross Milling Company P.O. Box 2696 Wichita, KS 67201	0.25
Oil	Durkee Industrial Foods 2333 Logan Boulevard Chicago, IL 60647	2
Salt	NaCl-CP granular or Morton™ Lite Salt® mixture Morton Salt Co. 110 N. Wacker Drive Chicago, IL 60606	2
Milk replacer	Land O Lakes 614 McKinley Place Minneapolis, MN 55413	4
Dough conditioner[b]	Cain Food Industries, Inc. P.O. Box 35066 3401 Sovereign Row Dallas, TX 75235	1.25
Water	As needed	≈ 65

[a]A composite of many hard wheat varieties harvested throughout the Great Plains in 1979.

[b]CDC-2500 contains wheat flour, emulsifiers (diacetyl tartaric acid esters of mono and diglycerides) dextrose, soy flour, lecithin, ascorbic acid and enzymes.
CDC-2500 Modified is equivalent to CDC-2500 without soy flour.

limit was set at 18 and depth of penetration was 10 mm. The curve was graphed at chart speed 100 mm per min. Peak height of the curve was measured as representative of the resistance of the crumb to compressibility.

Breads were analyzed for Na and K content using emission spectrographic methods 49.001-49.007 (AOAC 1980). Na/K ratio for each treatment was determined using the formula $\frac{\text{Na (g)}}{\text{K (g)}}$.

Sensory Evaluation of Breads

Ten persons between 20 and 50 years of age from the Department of Foods and Nutrition were selected for the panel on the basis of availability, interest and their sensitivity to bitterness within the range expected in a larger population. During the training period, panelists were familiarized with sensory procedures, standard bread characteristics and the scoring method used in this study. Panelists and panel leaders determined softness, gumminess, KCl bitterness and astringent mouthfeel to be the characteristics pertinent for this study. A 15 cm unstructured line, intensity scale anchored 1 cm from each end was used for evaluating each characteristic (Appendix, Figure A-2). The standard bread prepared with NaCl and no soy ingredients was designated for each characteristic on the score card. Four midmorning sessions per week, with four samples evaluated at each session, allowed all samples of a replication to be evaluated within a week.

The loaves were allowed to thaw one hour prior to sensory evaluation. Crusts were removed before cutting the 2.54 cm cubes and placing them on white odor-free plates. The samples, coded with 3 digit random numbers, were covered with waxed paper to prevent drying. Apple slices and a water rinse were provided for panelists' use between samples.

Analysis of Data

All data were analyzed by analysis of variance (ANOV). ANOV for volume and compressibility measurements and sensory data was as follows:

Source of variation	D/F
Treatment	16
Replication	2
Error	30
Total	48

The ANOV for Na/K ratio was:

Source of variation	D/F
Treatment	16
Replication	1
Error	16
Total	32

A randomized complete block design with sixteen treatment combinations was used. When significant differences were found for treatments or treatment combinations, least significant differences were used to compare means (SAS Institute 1982).

RESULTS AND DISCUSSION

F values and levels of significance from the ANOV for physical measurements are given in Table II. There was a significant difference in volume for salt ($P \leq 0.001$), dough conditioner ($P \leq 0.001$), milk replacer ($P \leq 0.05$) and oil ($P \leq 0.01$). A significant difference in softness measured by compressibility on the IUTM was found for milk replacer ($P \leq 0.05$). The interaction between dough conditioner and milk replacer was also significant ($P \leq 0.05$). Significant differences in Na/K ratio were found for salt ($P \leq 0.001$), dough conditioner ($P \leq 0.001$) and milk replacer ($P \leq 0.001$). A four-way interaction among these ingredients and oil was also significant ($P \leq 0.01$).

F values and levels of significance from the ANOV for sensory characteristics are given in Table III. No significant differences in softness were found. An interaction of dough conditioner and milk replacer was indicated for gumminess ($P \leq 0.05$), but dough conditioner had no effect on other attributes studied. Significant differences in KCl bitterness ($P \leq 0.001$) and astringent mouthfeel ($P \leq 0.001$) were found for salt.

Physical Measurements

Volume. In Table IV, the least squares means are given for volume of breads containing NaCl or Morton Lite Salt® mixture and soy or non-soy dough conditioner, milk replacer and oil. Loaf volumes were significantly higher ($P \leq 0.001$) for all breads containing the Lite Salt® mixture. Gassing power studies have shown that Lite Salt® inhibited yeast fermentation to a lesser extent than NaCl (Kulp 1982, Salovaara 1982b). Since breads in this study were proofed to time rather than to height, breads containing Lite Salt® would be expected to have higher volumes.

TABLE II

F Values and Level of Significance[a] for Physical Measurements of Breads

Ingredient	DF	Volume[b]	Compressibility[b]	Na/K ratio[c]
Salt (S)	1	86.03***	0.45	4542.72***
Dough Conditioner (DC)	1	16.15***	2.20	24.66***
Milk Replacer (MR)	1	3.96*	4.93*	23.54***
Oil (O)	1	7.89**	0.15	1.52
S × DC	1	0.01	1.91	16.42***
S × MR	1	0.64	0.22	3.50
S × O	1	0.00	0.07	5.24*
DC × MR	1	0.13	5.87*	5.53*
DC × O	1	0.00	0.64	119.87***
MR × O	1	0.33	2.85	50.39***
DC × MR × S	1	1.59	0.00	7.39*
DC × MR × O	1	0.14	0.72	20.48***
DC × S × O	1	0.02	0.03	75.07***
MR × S × O	1	0.03	2.43	56.61***
DC × MR × S × O	1	0.02	1.16	13.86**

[a]Level of significance is indicated as follows: *, $P \leq 0.05$; **, $P \leq 0.01$; ***, $P \leq 0.001$.

[b]Three replications.

[c]Two replications.

TABLE III

F Values and Level of Significance[a] for Bread Characteristics Determined by Sensory Analysis

Ingredient	DF	Softness[b]	Gumminess[b]	KCL Bitterness[b]	Astringent Mouthfeel[b]
Salt (S)	1	2.68	0.00	64.90***	58.01***
Dough conditioner (DC)	1	0.09	0.03	3.48	0.49
Milk replacer (MR)	1	0.10	1.65	0.26	1.59
Oil (O)	1	0.00	0.39	0.02	0.11
S × DC	1	0.54	0.60	3.97[c]	0.63
S × MR	1	0.44	0.00	0.50	0.51
S × O	1	0.21	0.09	0.02	0.25
DC × MR	1	0.30	5.52*	0.19	0.12
DC × O	1	0.51	0.01	0.04	0.22
MR × O	1	3.63	0.45	0.02	0.34
DC × MR × S	1	0.00	0.00	0.20	0.56
DC × MR × O	1	0.00	0.20	1.79	0.02
DC × S × O	1	1.07	0.22	0.69	0.28
MR × S × O	1	0.01	0.03	0.29	0.77
DC × MR × S × O	1	0.08	0.08	0.05	0.72

[a]Level of significance is indicated as follows: *, $P \leq 0.05$; **, $P \leq 0.01$; ***, $P \leq 0.001$.

[b]Three replications.

[c]Level of significance was $P < 0.056$.

TABLE IV

Least Squares Means for Volume[a] of Breads Containing NaCl or Morton™ Lite Salt® Mixture and Soy or Non-Soy Dough Conditioner, Milk Replacer and Oil

Ingredient	Volume[a] cc
Salt	
NaCl	936
Lite	971***[b]
Dough conditioner	
Soy	962
Non-soy	946***
Milk replacer	
Soy	957
Non-soy	950*
Oil	
Soy	960
Non-soy	949**

[a]Three replications.

[b]Level of significance is indicated as follows: *, $P \leq 0.05$; **, $P \leq 0.01$; ***, $P \leq 0.001$.

Significantly higher volumes also were noted for soy-containing milk replacer ($P \leq 0.05$), dough conditioner ($P \leq 0.001$) and oil ($P \leq 0.01$). The problem of depressed loaf volume previously reported in studies of breads containing soy flour has been overcome to a great extent by chemical treatment and through the use of surfactants; in some instances, low levels of soy products may enhance volume as seen in this study. Similarly, in preliminary work, we compared a non-soy and two soy-whey blends of milk replacers. The mean volumes of the two soy-whey blends studied (938 cc and 948 cc) were greater than volumes of breads containing no soy (900 cc) in the milk replacer.

Enhancement of volume by soy milk replacer could be attributed to its protein content. The soy-whey blends for this study contained more protein than the non-soy blend (35.5% and 20.5% respectively). Similarly, protein content of soy-whey milk replacers studied in preliminary work was greater (34.7%) than that of the non-soy blend (12.7%). The higher protein content and its possible contribution to bread structure may account for the greater volumes of soy-containing breads compared to non-soy breads. However, this explanation is questionable in light of the low levels (4%) of milk replacer used.

Another possible explanation for greater loaf volume is found in the mellowing effect that soy flour has on gluten protein. Addition of small amounts of soy flour mellows the gluten content of the flour and the dough becomes slightly more extensible (Ofelt et al 1952). Bruinsma (1983) stated that slight increases in volume are commonly seen when low levels of innocuous materials are added to strong flours as used in this study.

These explanations do not account for the increase in volume attributable to soy oil, and no studies comparing the effect of soy and non-soy oil on loaf volume were found. However, a study by Bruinsma and Finney (1982) of oils and oil-surfactant combinations provided volume data for breads containing 14 different oils. A similar trend of higher volumes in breads containing soy oil was evident. Clearly, the need for further investigation of soy as it affects loaf volume is indicated.

Compressibility. Least squares means for IUTM compressibility are reported in Table V. The dough conditioner-milk replacer interaction was significant ($P \leq 0.05$), and a significant difference was found between the two milk replacers with the non-soy ingredients giving the firmer breads. The softer crumb of breads containing soy flour has been attributed to the water holding capacity of soy flour (Steller and Mailey 1937, Ying and Geddes 1948, Turro and Sipos 1970). Furthermore, the greater loaf volume noted in soy-containing breads also might contribute to crumb softness.

Na/K Ratio. Comparison of mean values of Na/K ratio are given in Table VI. Breads containing Lite Salt® had significantly lower Na/K ratios than breads containing NaCl. A significant difference was found between the two milk replacers and dough conditioners with the soy ingredients giving the higher Na/K ratio. A four-way interaction of milk replacer, dough conditioner oil and salt was indicated with no apparent pattern.

Grain. The grain of all breads was rated satisfactory (Appendix, Figure A-3).

Sensory Evaluation

Softness. Although a difference in softness for dough conditioner-milk replacer was indicated by IUTM measurement, a similar significant difference was not detectable by sensory evaluation nor were significant differences in softness found for oil or salt.

TABLE V

Least Squares Means[a] for Instron Compressibility (kg)[b] of Breads Containing Soy or Non-Soy Dough Conditioner and Milk Replacer

		Milk Replacer	
		Soy	Non-Soy
Dough Conditioner	Soy	0.66	0.65
	Non-Soy	0.63	0.78*

[a]Three replications.

[b]Level of significance is indicated as follows: *, $P \leq 0.05$; **, $P \leq 0.01$; ***, $P \leq 0.001$.

TABLE VI

Comparison of Mean Values[a] for Na/K Ratio[b]

Treatment Combination				
Dough Conditioner	Milk Replacer	Salt	Oil	Mean
NS[c]	NS	Lite	NS	0.63[abe]
NS	NS	Lite	S[d]	0.73[abef]
NS	NS	NaCl	NS	2.78[c]
NS	NS	NaCl	S	2.55[dg]
NS	S	Lite	NS	0.71[bef]
NS	S	Lite	S	0.83[abef]
NS	S	NaCl	NS	2.41[dg]
NS	S	NaCl	S	3.72[h]
S	NS	Lite	NS	0.70[abef]
S	NS	Lite	S	0.70[abef]
S	NS	NaCl	NS	3.64[hi]
S	NS	NaCl	S	2.64[cd]
S	S	Lite	NS	0.86[bef]
S	S	Lite	S	0.77[abef]
S	S	NaCl	NS	3.48[i]
S	S	NaCl	S	2.92[c]

[a]Two replications.

[b]Values with common superscripts are not significantly different.

[c]NS = non-soy.

[d]S = soy.

Gumminess. Least squares means for gumminess are reported in Table VII. There was a significant difference ($P \leq 0.05$) in gumminess for dough conditioner and milk replacer interaction with breads containing non-soy dough conditioner and milk replacer rated more gummy than their soy-containing counterparts. It is noteworthy that breads evaluated as more firm by IUTM measurement also contained this treatment combination. It is possible that the characteristic of firmness evaluated by IUTM measurement was the attribute panelists referred to as gumminess. No significant differences in gumminess were attributed to salt or oil.

Astringent Mouthfeel. Astringent mouthfeel was significant ($P \leq 0.001$) for type of salt (Table VIII). Breads containing Morton Lite Salt® mixture were given a significantly higher mean rating (5.2) for astringent mouthfeel than the mean score given to breads containing NaCl (3.4), Kulp (1982) reported similar astringency in breads containing Morton Lite Salt® mixture at both the 1.5% and 2.2% levels. Neither milk replacer, dough conditioner nor oil (soy and non-soy) had a significant effect on astringent mouthfeel.

KCl Bitterness. Least squares means for KCl bitterness are reported in Table VIII. The scores for bitterness were consistently higher for Morton Lite Salt® mixture than for NaCl. Similar results have been reported in studies evaluating 50% replacement of NaCl (2% level) with KCl (Kulp 1982, Salovaara 1982). However, in this study the mean score for KCl bitterness in breads containing Lite Salt® with all treatments pooled was only 5.1 on a scale having 13.0 as the highest point.

The interaction of dough conditioner and salt was significant for bitterness at the $P \leq 0.056$ level (Table IX). When the Lite Salt® was used with soy dough conditioner, scores for bitterness were lower (4.6)

TABLE VII

Least Squares Means[a] for Sensory Gumminess[b] of Breads Containing Soy or Non-Soy Milk Replacer and Dough Conditioner

		Milk Replacer	
		Soy	Non-Soy
Dough Conditioner	Soy	3.7	3.5
	Non-Soy	3.1	4.0*

[a]Three replications.

[b]Level of significance is indicated as follows: *, $P \leq 0.05$; **, $P \leq 0.01$; ***, $P \leq 0.001$.

TABLE VIII

Least Squares Means for KCl Bitterness and Astringent Mouthfeel of Breads Containing NaCl or Morton™ Lite Salt® Mixture

Ingredient	KCl Bitterness[a]	Astringent Mouthfeel[a]
NaCl	3.3	3.4
Morton™ Lite Salt® mixture	5.1***[b]	5.2***[b]

[a]Three replications.

[b]Level of significance is indicated as follows: *, $P \leq 0.05$; **, $P \leq 0.01$; ***, $P \leq 0.001$.

TABLE IX

Least Squares Means[a] for KCl Bitterness of Breads Containing NaCl or Morton™ Lite Salt® Mixture and Dough Conditioner

		NaCl	Lite
Dough Conditioner	Soy	3.3	4.6[b]
	Non-Soy	3.3	5.5

[a]Three replications.

[b]Level of significance $P \leq 0.056$.

than when non-soy dough conditioner was used (5.5). Some masking potential by the very low levels of soy dough conditioner therefore is indicated.

Preliminary studies of KCl bitterness in white pan breads indicated that soy oil may enhance the atypical flavor notes of Morton Lite Salt® mixture. In a similar study using Lite Salt®, Dreese (1983) reported a more intense bitterness in breads in which soy oil was used. Neither of the formulations in those two studies included milk replacer and dough conditioner. In the present study, the bread formulation did include both milk replacer and dough conditioner, and no significant difference in KCl bitterness for oil was found. This suggests that milk replacer and dough conditioner may have a masking effect on bitterness. It is noteworthy that when mean scores for bitterness are ranked (Table X) breads with soy dough conditioner and non-soy oil were judged the least bitter of the Lite Salt®- containing breads. Conversely, the breads judged most bitter contained non-soy dough conditioner and soy oil.

Additional studies to compare bitterness of Lite Salt®- containing breads with and without dough conditioner and milk replacer are needed. Kulp et al (1982) and Salovaara (1982a) described KCl bitterness as very intense. A similar rating of the intensity of KCl bitterness of breads prepared for this study was not indicated. Furthermore, panelists consistently commented that none of the breads was objectionable and atypical flavor notes were not readily detectable.

TABLE X

Ranked Mean Scores[a] for Bitterness and Astringency for Breads With and Without Soy Ingredients

Bitterness					Astringency				
Treatment Combination					Treatment Combination				
Dough Condi-tioner	Milk Replacer	Oil	Salt		Dough Condi-tioner	Milk Replacer	Oil	Salt	
S[b]	NS[c]	S	NaCl	2.87	S	S	NS	NaCl	3.12
NS	S	S	NaCl	3.18	S	NS	S	NaCl	3.15
NS	NS	NS	NaCl	3.19	NS	S	NS	NaCl	3.19
NS	S	NS	NaCl	3.23	NS	NS	NS	NaCl	3.34
S	S	NS	NaCl	3.25	NS	NS	S	NaCl	3.50
S	NS	NS	NaCl	3.51	S	S	S	NaCl	3.51
NS	NS	S	NaCl	3.52	NS	S	S	NaCl	3.58
S	S	S	NaCl	3.60	S	NS	NS	NaCl	3.93
S	S	NS	Lite	4.29	S	S	S	Lite	4.73
S	NS	NS	Lite	4.71	NS	S	S	Lite	4.97
S	S	S	Lite	4.73	NS	S	NS	Lite	5.09
S	NS	S	Lite	4.85	S	NS	NS	Lite	5.12
NS	S	S	Lite	5.11	S	S	NS	Lite	5.15
NS	NS	NS	Lite	5.54	S	NS	S	Lite	5.17
NS	S	NS	Lite	5.61	NS	NS	S	Lite	5.61
NS	NS	S	Lite	5.72	NS	NS	NS	Lite	5.92

[a]Three replications.

[b]S = soy.

[c]NS = non-soy.

SUMMARY AND CONCLUSIONS

White pan breads containing three soy ingredients (milk replacer, dough conditioner and oil) were evaluated and compared to non-soy containing breads to determine the effect of soy on the atypical flavor notes of Morton Lite Salt® mixture. Differences among the breads in volume, compressibility and Na/K ratio also were determined.

Use of Lite Salt® in white pan bread shortened proof time and significantly decreased Na/K ratio. Soy ingredients had no effect on bread softness or gumminess and did not intensify astringent mouthfeel and/or KCl bitterness of breads containing Lite Salt®. To the contrary, soy dough conditioner appeared to have some masking effect on bitterness. In addition, breads containing soy ingredients were significantly softer and had greater volumes than the non-soy-containing breads.

Lite Salt®-containing breads are consistently rated more bitter and have a more astringent mouthfeel than breads with NaCl. Additional studies are needed to further explore the effect of a variety of bread ingredients on the masking of these organoleptic properties.

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APPENDIX

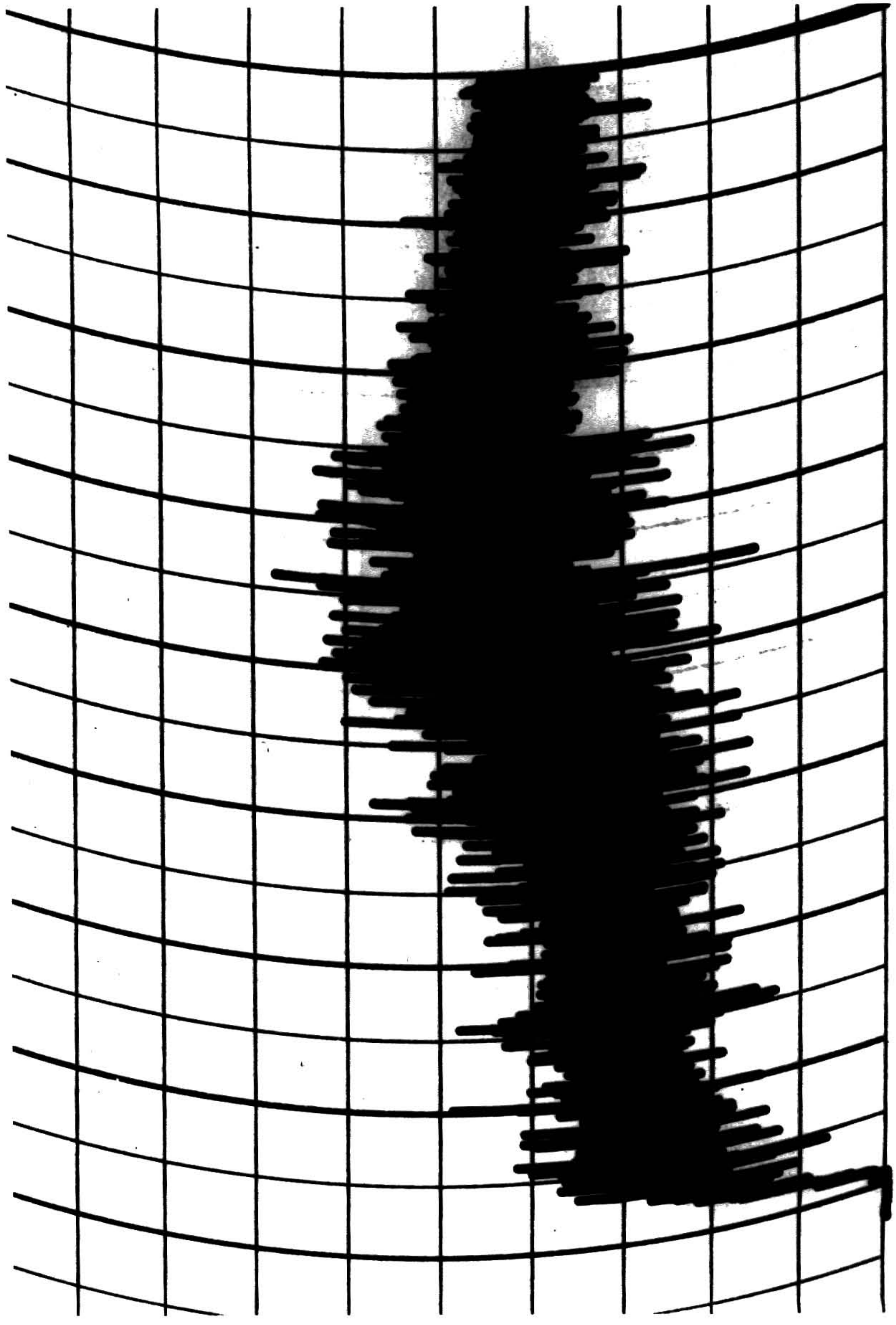


TABLE A-I

Milk Replacer Specifications[a]

	Ayrlac 260 (corn/whey blend)	Ayrlac 550 (soy/whey blend)
Protein	20.50%	35.50%
Moisture	5.00%	5.00%
Carbohydrate	64.00%	51.00%
Fat	1.75%	0.90%
Minerals (ash)	6.50%	6.50%
pH	6.2	6.5
Color	Cream	Cream
Flavor	No off-flavor	No off-flavor

[a]Land O Lakes, Inc., 614 McKinley Place, Minneapolis, Minnesota 55413.

TABLE A-II

Treatment Combinations[a]

	Oils		Dough Conditioners		Milk Replacers	
Treatment	Soy	Cottonseed	Soy	Non-soy	Soy/Whey	Corn/Whey
1	X		X			X
2	X			X		X
3	X		X		X	
4	X			X	X	
5		X	X			X
6		X		X		X
7		X	X		X	
8		X		X	X	

[a]Each treatment combination was prepared with NaCl and Lite Salt® mixture.

TABLE A-III

Solutions Used in Preparation of Bread Samples[a]

Ingredient	% of Flour Wt	Stock Solution g/100 ml	Pipetted Solution ml/Loaf	Pipetted Solution Ingred, g	Pipetted Solution Water, ml
Yeast	5.25	12.12	40	5.25	35.28
Malt[b]	0.25	2.50	5	0.25	5.00
Salt	2.00	25.00	8	2.00	7.10
Sugar	6.00	60.00	10	6.00	6.90
					54.28[c]
					Total water/loaf

[a]Based on 100% flour.

[b]As a water extract equivalent to 0.25% malted barley.

[c]Water added as needed to meet flour absorption requirements (65 ml).

Fig. A-2. Semi-structured line rating scales used by the panelists for evaluating white pan breads is shown. The ratings of standard NaCl-containing breads for each characteristic as determined in training sessions and designated on subsequent questionnaires are indicated.

Questionnaire for White Pan Bread

Name ______________________________ Date ________________

Please evaluate the softness, bitterness, gumminess and mouthfeel of these samples of bread. Make vertical lines on each of the horizontal lines to indicate your rating of each sample. Label each vertical line with the code number of the sample it represents.

Taste the samples in the following order:

Softness

Very Soft — Standard — Very firm

Gumminess

No gumminess Standard — Very gummy

KCl bitterness

None Standard — Intense

Astringent mouthfeel

None Standard — Intense

Fig. A-3. Representative breads for each of the 16 treatments are shown. In each of the pairs, the odd-numbered bread contains NaCl; the even-numbered contains Lite Salt®.

Breads 1 and 2 contain non-soy milk replacer, non-soy dough conditioner and non-soy oil.

Breads 3 and 4 contain non-soy milk replacer, non-soy dough conditioner and soy oil.

Breads 5 and 6 contain non-soy milk replacer, soy dough conditioner and non-soy oil.

Breads 7 and 8 contain non-soy milk replacer, soy dough conditioner and soy oil.

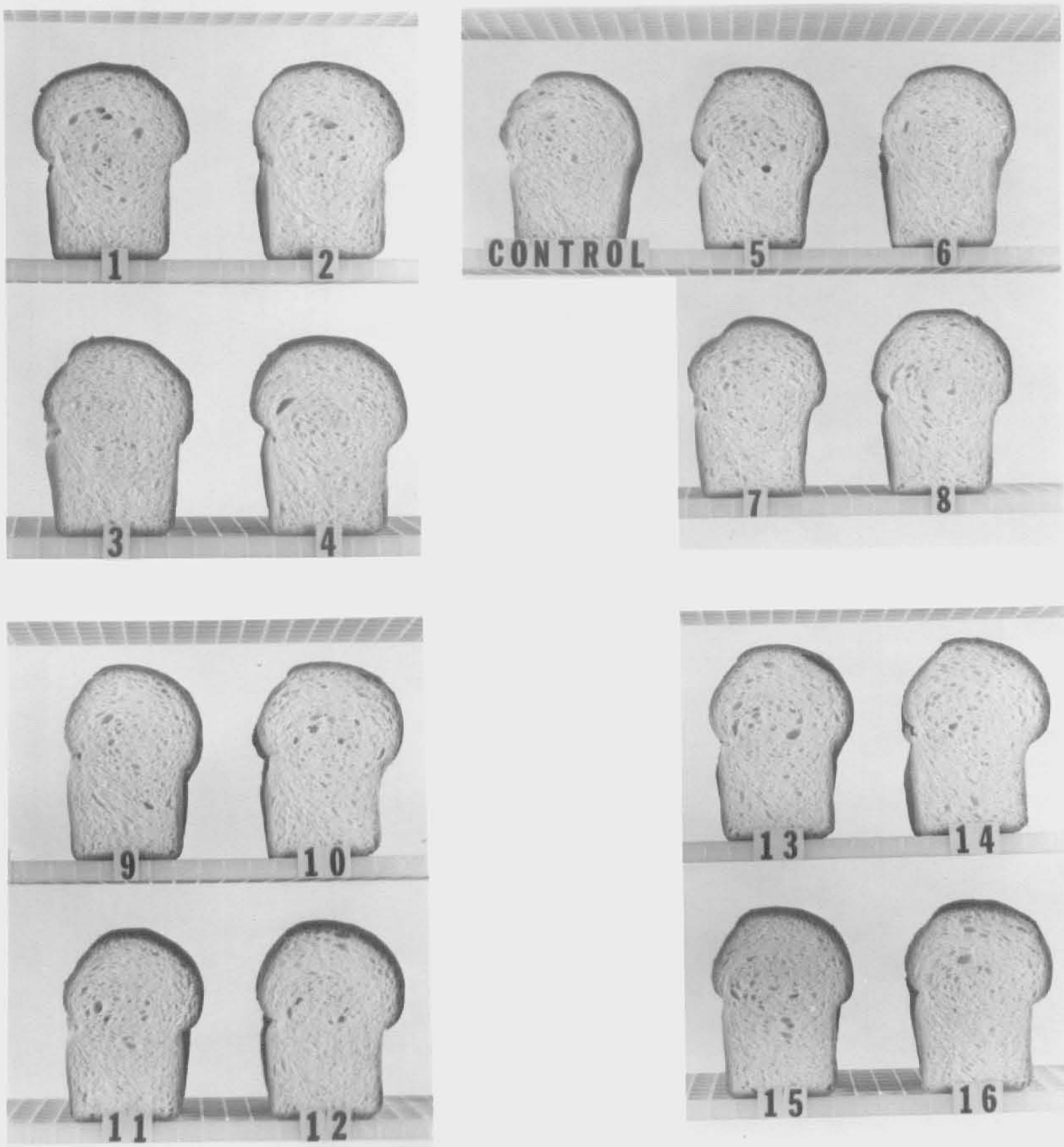
Breads 9 and 10 contain soy milk replacer, non-soy dough conditioner and non-soy oil.

Breads 11 and 12 contain soy milk replacer, non-soy dough conditioner and soy oil.

Breads 13 and 14 contain soy milk replacer, soy dough conditioner and non-soy oil.

Breads 15 and 16 contain soy milk replacer, soy dough conditioner and soy oil.

For comparison purposes, a control containing NaCl and no soy ingredients is indicated.


1
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16

TABLE A-IV

Mean Values for Volume, Instron Compressibility and Na/K Ratio

Treatment						
Dough Conditioner	Milk Replacer	Salt	Oil	Volume[a]	Instron Compressibility[a]	Na/K[b]
NS[c]	NS	Lite	NS	954.2	0.70	0.63
NS	NS	Lite	S[d]	963.8	0.80	0.73
NS	NS	NaCl	NS	919.6	0.79	2.78
NS	NS	NaCl	S	930.0	0.82	2.55
NS	S	Lite	NS	964.2	0.58	0.71
NS	S	Lite	S	975.4	0.59	0.83
NS	S	NaCl	NS	926.3	0.66	2.41
NS	S	NaCl	S	937.9	0.67	3.72
S	NS	Lite	NS	976.9	0.59	0.70
S	NS	Lite	S	983.8	0.75	0.70
S	NS	NaCl	NS	933.4	0.64	3.64
S	NS	NaCl	S	940.9	0.62	2.64
S	S	Lite	NS	970.4	0.75	0.86
S	S	Lite	S	986.9	0.57	0.77
S	S	NaCl	NS	945.0	0.66	3.48
S	S	NaCl	S	957.5	0.65	2.92

[a]Three replications.

[b]Two replications.

[c]NS = non-soy.

[d]S = soy.

TABLE A-V

Mean Values[a] for Sensory Softness, Gumminess, KCl Bitterness and Astringent Mouthfeel

Treatment							
Dough Conditioner	Milk Replacer	Salt	Oil	Softness	Gumminess	KCl Bitterness	Astringent Mouthfeel
NS[b]	NS	KCl	NS	4.04	3.94	5.54	5.92
NS	NS	KCl	S[c]	4.27	3.93	5.72	5.61
NS	NS	NaCl	NS	4.12	4.16	3.19	3.34
NS	NS	NaCl	S	4.85	4.01	3.52	3.50
NS	S	KCl	NS	4.35	3.20	5.61	5.09
NS	S	KCl	S	3.80	2.86	5.11	4.97
NS	S	NaCl	NS	4.60	3.24	3.23	3.19
NS	S	NaCl	S	4.69	3.20	3.18	3.58
S	NS	KCl	NS	4.32	3.46	4.72	5.12
S	NS	KCl	S	4.59	3.72	4.85	5.17
S	NS	NaCl	NS	4.40	3.40	3.51	3.93
S	NS	NaCl	S	4.59	3.35	2.87	3.15
S	S	KCl	NS	4.33	3.95	4.29	5.15
S	S	KCl	S	3.99	3.72	4.73	4.73
S	S	NaCl	NS	4.81	3.98	3.25	3.12
S	S	NaCl	S	4.12	3.31	3.60	3.51

[a]Three replications.

[b]NS = non-soy.

[c]S = soy.

FLAVOR INTERACTIONS OF SOY AND POTASSIUM CHLORIDE IN MORTON^{TM} LITE SALT® MIXTURE IN WHITE PAN BREAD

by

MEREDITH PEARSON STROH

B.S., University of Wisconsin, 1968

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Foods and Nutrition

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1983

ABSTRACT

The physical and sensory characteristics of white pan breads containing Morton Lite Salt® mixture were evaluated. Soy and non-soy dough conditioners, milk replacers and oil were tested in all possible combinations with 2% Lite Salt®. Volume, bread crumb softness, gumminess and Na/K ratio were determined. Sensory characteristics were evaluated to determine if an interaction of soy and KCl rather than KCl itself were responsible for atypical flavor notes in yeast breads made with the Lite Salt®. A randomized complete block design with sixteen treatment combinations was used.

Analysis of variance of physical data revealed Morton Lite Salt® mixture shortened proof time and significantly decreased Na/K ratio. The grains of all breads containing Lite Salt® were judged to be satisfactory. Soy-containing ingredients with either Lite Salt® or NaCl resulted in softer breads with significantly higher volumes than when non-soy ingredients were used.

A ten-member panel, representing a normal range of sensitivities to bitterness scored breads with Lite Salt® as more bitter and having a more astringent mouthfeel than breads with NaCl. Soy-containing dough conditioners demonstrated some ability to mask bitterness.