Evaluation of sauerkraut prepared with potassium chloride as a complete or partial replacement for sodium chloride

Karen Lenise Guy Jones
To the Graduate Council:

I am submitting herewith a thesis written by Karen Lenise Guy Jones entitled "Evaluation of sauerkraut prepared with potassium chloride as a complete or partial replacement for sodium chloride." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

John R. Mount, Major Professor

We have read this thesis and recommend its acceptance:

P. Michael Davidson, David L. Coffey

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)
To the Graduate Council:

I am submitting herewith a thesis written by Karen Lenise Guy Jones entitled "Evaluation of Sauerkraut Prepared with Potassium Chloride as a Complete or Partial Replacement for Sodium Chloride." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

John R. Mount, Major Professor

We have read this thesis and recommend its acceptance:

Michael Davide

David L. Coffey

Accepted for the Council:

Vice Provost
and Dean of the Graduate School
STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Master of Science degree at The University of Tennessee, Knoxville, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of the source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Head of Interlibrary Services when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature  Karen Lenise Guy Jones
Date  May 22, 1986
EVALUATION OF SAUERKRAUT PREPARED WITH
POTASSIUM CHLORIDE AS A COMPLETE OR
PARTIAL REPLACEMENT FOR SODIUM CHLORIDE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Karen Lenise Guy Jones
June 1986
DEDICATION

To my parents, Myles and Ruth, who gave me love, support, and encouragement to achieve my scholastic goals.
ACKNOWLEDGMENTS

The author expresses her sincere appreciation and thanks to Dr. John R. Mount for serving as major professor and for his patience, knowledge, guidance, and friendship through the course of this study. Appreciation is also extended to Dr. P. Michael Davidson and Dr. David L. Coffey for their assistance as committee members.

Special thanks are given to Dr. J. T. Miles, former department head, and Dr. Hugh O. Jaynes, present department head, for providing support and the necessary facilities within the Food Technology and Science Department.

Lastly, the author expresses deepest appreciation and thanks to her husband, Dennis, for his help, patience, love and understanding during the course of this study.
ABSTRACT

The purpose of this study was to develop sauerkraut products using potassium chloride as a complete or partial sodium chloride replacement, to determine the microbiological and chemical safety of the products, and to determine the consumer acceptance of the sauerkraut.

Sauerkraut was prepared with 3 different salts as treatments: sodium chloride, potassium chloride, and Morton Lite Salt^R. The fermentations were allowed to proceed for 30 days while total microbial counts, lactic acid-producing bacterial counts, yeast and mold counts, and titratable acidities were being monitored.

Total and lactic microbial counts for the potassium chloride and Lite Salt treatments were found to be higher than counts for the sodium chloride treatments. This was due to the lower ionic strength of the potassium chloride in the brine, allowing for greater microbial growth and therefore, greater lactic acid production as was evidenced by the higher titratable acidities of these treatments.

Sauerkraut juice components were analyzed with an HPLC instrument and no differences were found in the types and quantities of components present in the 3 treatments.

Total amounts of sodium and potassium in the finished sauerkraut products were determined by atomic absorption spectrophotometric analyses. Sodium reduction in the kraut prepared with potassium chloride instead of sodium chloride
is about 98%. Kraut prepared with Lite Salt shows a reduction in sodium of 40-45% over that prepared with sodium chloride.

Sensory evaluation using an untrained consumer-type panel showed kraut prepared with Lite Salt compared favorably to kraut prepared with sodium chloride. No bitter aftertaste of the Lite Salt was noted due to the masking of this flavor by the lactic acid. Sauerkraut prepared with potassium chloride was rated lower than the other two treatments due to its bitter, metallic aftertaste.

This study shows that potassium chloride can be used as at least a partial replacement for sodium chloride in the fermentation of sauerkraut. Use of Lite Salt provides a microbiologically and chemically safe product that is not only palatable but compares favorably to kraut prepared with sodium chloride, yet provides a substantial amount of sodium reduction over common sauerkraut.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II. REVIEW OF THE LITERATURE</td>
<td>4</td>
</tr>
<tr>
<td>Sauerkraut</td>
<td>4</td>
</tr>
<tr>
<td>History</td>
<td>4</td>
</tr>
<tr>
<td>Commercial Preparation</td>
<td>5</td>
</tr>
<tr>
<td>Fermentation</td>
<td>6</td>
</tr>
<tr>
<td>Sequence of Microorganisms</td>
<td>7</td>
</tr>
<tr>
<td>Influence of Sodium Chloride</td>
<td>9</td>
</tr>
<tr>
<td>Influence of Temperature</td>
<td>11</td>
</tr>
<tr>
<td>Use of Salt Substitutes</td>
<td>13</td>
</tr>
<tr>
<td>Sodium Chloride in the Diet</td>
<td>13</td>
</tr>
<tr>
<td>Sodium Chloride-Potassium Chloride Mixtures</td>
<td>14</td>
</tr>
<tr>
<td>III. MATERIALS AND METHODS</td>
<td>18</td>
</tr>
<tr>
<td>Preparation of Cabbage</td>
<td>18</td>
</tr>
<tr>
<td>Fermentation Procedure</td>
<td>18</td>
</tr>
<tr>
<td>Sample Collection</td>
<td>19</td>
</tr>
<tr>
<td>Microbiological Analysis</td>
<td>19</td>
</tr>
<tr>
<td>Chemical Analysis</td>
<td>20</td>
</tr>
<tr>
<td>Titratable Acidity</td>
<td>20</td>
</tr>
<tr>
<td>Juice Evaluation by HPLC</td>
<td>20</td>
</tr>
<tr>
<td>Sodium/Potassium Determination</td>
<td>21</td>
</tr>
<tr>
<td>Sample Storage after Fermentation</td>
<td>21</td>
</tr>
<tr>
<td>Sensory Evaluation</td>
<td>22</td>
</tr>
<tr>
<td>Experimental Design</td>
<td>22</td>
</tr>
<tr>
<td>IV. RESULTS AND DISCUSSION</td>
<td>24</td>
</tr>
<tr>
<td>Microbiological Analysis</td>
<td>24</td>
</tr>
<tr>
<td>Chemical Analyses</td>
<td>32</td>
</tr>
<tr>
<td>Titratable Acidity</td>
<td>32</td>
</tr>
<tr>
<td>HPLC Analysis</td>
<td>36</td>
</tr>
<tr>
<td>Sodium/Potassium Determination</td>
<td>36</td>
</tr>
<tr>
<td>Sensory Evaluation</td>
<td>36</td>
</tr>
<tr>
<td>V. SUMMARY AND CONCLUSIONS</td>
<td>41</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>44</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>49</td>
</tr>
<tr>
<td>VITA</td>
<td>52</td>
</tr>
</tbody>
</table>
### LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. F-Ratios and Error Mean Squares for Total and Lactic Microbial Counts of Sauerkraut</td>
<td>27</td>
</tr>
<tr>
<td>2. F-Ratios and Error Mean Square for Yeast and Mold Counts of Sauerkraut</td>
<td>31</td>
</tr>
<tr>
<td>3. F-Ratios and Error Mean Square for Titratable Acidity Values of Sauerkraut</td>
<td>33</td>
</tr>
<tr>
<td>4. F-Ratios and Error Mean Squares for HPLC Acid Analyses of Sauerkraut</td>
<td>37</td>
</tr>
<tr>
<td>5. Means for the Sodium/Potassium Determinations</td>
<td>38</td>
</tr>
<tr>
<td>6. Means for the Sensory Evaluation</td>
<td>40</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sensory evaluation score sheet for sauerkraut.</td>
<td>23</td>
</tr>
<tr>
<td>2. Average microbial counts on MRS and PCA over 30 days of sauerkraut fermentation period.</td>
<td>25</td>
</tr>
<tr>
<td>3. Average treatment microbial counts on PCA over 30 days of sauerkraut fermentation period.</td>
<td>28</td>
</tr>
<tr>
<td>4. Average treatment microbial counts on MRS over 30 days of sauerkraut fermentation period.</td>
<td>29</td>
</tr>
<tr>
<td>5. Average treatment titratable acidity values over 30 days of sauerkraut fermentation period.</td>
<td>34</td>
</tr>
<tr>
<td>6. Average treatment daily rates of acid production</td>
<td>35</td>
</tr>
<tr>
<td>A1. Average treatment log microbial counts on PCA over 30 days of sauerkraut fermentation period.</td>
<td>50</td>
</tr>
<tr>
<td>A2. Average treatment log microbial counts on MRS over 30 days of sauerkraut fermentation period.</td>
<td>51</td>
</tr>
</tbody>
</table>
CHAPTER I

INTRODUCTION

Sauerkraut is a naturally fermented green cabbage product. Its name is of German origin and literally means "acid cabbage." The use of cabbage in the human diet dates back to about 200 B.C. in Rome. Dutch "zoorkool," a product made from cabbage and salt, or sodium chloride, was described as early as 1772 (Pederson, 1979; Pederson and Albury, 1969). In the past there was little or no standardization of methods in sauerkraut production. Most of the information leading to current production methods has been obtained from research conducted in the past 80 years.

The preparation of sauerkraut involves dry salting of shredded or chopped cabbage with sodium chloride. The salt withdraws water and nutrients from the cabbage tissue, providing an appropriate medium for the growth of a sequence of lactic acid-producing bacteria which ferment the sugars contained in the cabbage. Salt, along with the acid and carbon dioxide produced by the bacteria, inhibits the growth of undesirable microorganisms in the medium. The salt also enhances the flavor of the final product.

Sodium chloride is an essential part of the human diet. Sodium is contained in all body fluids and helps to regulate fluid volume and osmotic pressure. Recently there has been much concern about the amount of salt consumed by Americans.
Sodium has been linked to hypertension in many studies (Dahl, 1958 and 1972; Frank and Mickelson, 1969; Haddy, 1980). The exact amount of sodium required by humans is difficult to determine. However, most Americans consume approximately 20 times the estimated daily requirement of 200 mg (IFT, 1980).

Sodium is found in many forms in processed food products. Sodium chloride, however, is the most common form utilized in fruit and vegetable products, meats, and bakery products. Fermented foods, such as sauerkraut, contain relatively large amounts of sodium in the form of sodium chloride which is used to alter the environment within the food and control microbial actions.

A possible replacement for sodium salts in foods are the potassium forms. One drawback to the use of potassium is its bitter, metallic aftertaste. However, potassium chloride can be used to replace sodium chloride by up to 50% in some food products with no significant flavor changes. Morton Lite SaltR, a mixture of equal parts of sodium chloride and potassium chloride, is just one of the many commercially-marketed, reduced-sodium salt products available for consumer use (Morton, 1981 and 1983).

It may also be possible to use potassium chloride to replace sodium chloride in some fermented food products. The objectives of this study were to develop sauerkraut products using potassium chloride as a complete or partial
sodium chloride replacement, to determine the microbiological and chemical safety of the products, and to determine the consumer acceptance of the sauerkraut.
CHAPTER II

REVIEW OF THE LITERATURE

1. SAUERKRAUT

A. History

The basic ingredient of sauerkraut is cabbage, which has been an important part of the diet of many civilizations since approximately 200 B.C. It was a very important cultivated crop in the Roman Empire because it was used in the treatment of various diseases. Cabbage is a temperate climate crop native to many areas. Large white heads of cabbage were commonly grown in many regions of the North Temperate Zone in Europe (Pederson, 1979).

The term "sauerkraut" is of Germanic origin but the product has its roots elsewhere. The earliest predecessors of sauerkraut were prepared by soaking cabbage leaves in vinegar or sour wine. The French product "choucroute" was prepared with either of these liquids added to broken or cut pieces of cabbage. Salt was then added to the mixture. The Germans shredded cabbage and layered it with salt, juniper berries, pepper roots, and spices in order to preserve it for winter consumption (Pederson, 1979). Dutch "zoorkool" was one of the first sauerkraut products produced using methods similar to those used in commercial sauerkraut production today. The cabbage was sprinkled with salt but
the standard quantity added is unknown since very little standardization of methods existed (Pederson and Albury, 1969). Most of the information leading to current sauerkraut production methods has been obtained from research conducted during the past 80 years.

B. Commercial Preparation

Present-day commercial preparation of sauerkraut involves dry-salting of shredded or chopped cabbage with sodium chloride. The process begins by trimming the outer leaves from the cabbage to remove dirt and undesirable microorganisms. The cabbage heads may then be rinsed with water and cored before chopping or shredding to about 1/32 of an inch (Pederson, 1979).

Historically, the cabbage was held for fermentation in stone crocks, kegs, or wooden vats or barrels. Most processors today use fiber glass or plastic-lined concrete tanks (Downing and Stamer, 1974). Salt is most commonly applied mechanically at the 2.25% w/w level. It must be evenly distributed in the cabbage to prevent problems during the fermentation process. However, it has been found that salt concentrations may vary within the vat.

The first definition of sauerkraut by the Federal Food and Drug Administration specified cabbage to be fermented in the presence of not less than 2% and not more than 3% salt (Pederson and Albury, 1969). The United States Department
of Agriculture grade standards (7 CFR 52.2963) for sauerkraut specify that the level of salt in the finished product must be between 1.3% and 2.5% expressed as sodium chloride (Code of Federal Regulations, 1982).

Salting, and subsequent packing, of the cut cabbage withdraws water, sugars, and other nutrients from the cabbage tissue, producing a brine shortly after mixing of the salt in the tanks of cabbage. A flexible plastic sheet, large enough to extend over the edges of the tank, is applied to the top of the mixture, and water or brine is placed on this cover to act as a weight. This helps form an effective seal, submerge the cabbage in brine, maintain sanitary conditions, repress the growth of undesirable microorganisms by creating a more anaerobic environment, and reduce oxidation, discoloration, and surface layer spoilage (Downing and Stamer, 1974; Pederson, 1979).

C. Fermentation

Sauerkraut is a naturally fermented product. This means the microorganisms that ferment the sugars contained in the cabbage are present on the surface of the vegetable when harvested. The chopped cabbage does not require inoculation with the proper microorganisms for a lactic acid fermentation to occur.

The sauerkraut fermentation is complex due to many factors. Acidity, pH, buffering capacity, natural plant
inhibitory compounds, and amount and availability of nutrients are all factors that can influence the fermentation (Fleming and McFeeters, 1981). Very early fermentation studies suggested a sequence of microorganisms that produce acid and flavor compounds in kraut (Parmele et al., 1927; Pederson, 1930; Priehm et al., 1927). Salt content and temperature fluctuations can influence this sequence to provide good or poor quality kraut. These factors tend to modify and direct the microbial interactions.

Gram-negative organisms which produce little or no acid and act as spoilage agents are present on the cabbage when it is harvested. They are classified as various soil and soft rot microorganisms (Pederson, 1930). Excessive growth of these organisms can interfere with the growth of the acid formers, cause dark kraut, and produce undesirable flavors (Fulde and Fabian, 1953). The lactic acid bacteria begin the fermentation and produce acid and carbon dioxide that generally inhibit the growth of the Gram-negative organisms.

Sequence of Microorganisms

The fermentation is initiated by the Gram-positive, heterofermentative, coccoid bacteria, *Leuconostoc mesenteroides* (Pederson, 1930). This organism, when grown in cabbage juice, has a shorter lag phase and a more rapid generation time than the other microorganisms associated with the fermentation. This explains its occurrence prior to the other microorganisms. It is also the most sensitive
to increased acid production and rapid decline in pH values (Stamer et al., 1971; Stamer, 1975). Parmele et al. (1927) recognized that the bacteria that initiate the fermentation could not withstand high concentrations of acid as could the microorganisms which succeeded them.

*L. mesenteroides* will ferment glucose to a mixture of end products composed of approximately 45% lactic acid, 25% carbon dioxide and 25% acetic acid and ethanol. Fructose may be partially reduced to mannitol (Pederson and Albury, 1969).

Two other microorganisms, *Lactobacillus brevis* and *Lactobacillus plantarum*, follow *L. mesenteroides*. *Lactobacillus brevis* is a Gram-positive, rod-shaped bacterium that produces the same end products from sugars as does *L. mesenteroides*, but produces a higher concentration of acid. *Lactobacillus plantarum* is a homofermentative, Gram-positive, rod-shaped bacterium. It produces the greatest amount of lactic acid during the fermentation as this is its major end product (Pederson and Albury, 1969).

Two other bacteria have been observed to participate in some sauerkraut fermentations. *Pediococcus cerevisiae* and *Streptococcus faecalis* are Gram-positive, homofermentative, coccoid bacteria that ferment sugars primarily to lactic acid. *Pediococcus cerevisiae* is the more common of the two, but neither plays a major role in most sauerkraut fermentations (Pederson and Albury, 1969).
The heterofermenters begin the fermentation by producing acids along with other end products. They only provide a titratable acidity of 0.7% to 0.9% and cannot complete the fermentation. The homofermenters, producing lactic acid as their primary end product, finish the fermentation to a titratable acidity of 1.5% to 2.0% and may even utilize some of the mannitol produced by the heterofermenters (Pederson, 1930).

According to Brock (1979) the homofermenters break down hexoses via the hexose diphosphate pathway to pyruvate. The pyruvate is then converted to lactic acid. The heterofermenters utilize the hexose monophosphate pathway to break down hexose to pyruvate and acetyl phosphate. Carbon dioxide is released during the process. The pyruvate is converted to lactic acid and the acetyl phosphate is processed to ethanol and acetic acid.

The growth of each species during the fermentation depends on its initial presence in the cut cabbage, the nutrient composition of the cabbage, and also its fineness of cut. Many environmental factors can influence the bacteria and the fermentation. The most important and most controllable of these are salt concentration and temperature.

**Influence of Sodium Chloride**

Salt, or sodium chloride, is added to the shredded or chopped cabbage to withdraw water and nutrients from the
cabbage tissue to provide an appropriate medium for the growth of the lactic acid bacteria. The salt, along with the lactic acid produced by the bacteria, inhibits the growth of undesirable microorganisms in the medium and functions also to enhance the flavor of the final product.

Pederson and Albury (1954) showed that a low salt concentration of 1.0% is advantageous to the growth of the heterofermenters while a high salt concentration of 3.5% is more detrimental to their growth than to that of the homofermenters. Heterofermentative bacteria, grown in cabbage juice with 3.5% salt added, produced 90% less acid than those grown in juice with no added salt. The homofermenters only showed a 30% reduction in acid production at this salt level. Therefore, salt concentration may have an effect on the rate of acid production due to altered growth rates of the bacteria (Stamer, 1975).

Researchers found that kraut prepared with low salt concentrations had a good color but a soft texture. The kraut prepared with a high salt concentration had poor color and flavor and a tough texture (Pederson and Albury, 1954). The high salt levels often influence the growth of yeasts that may cause a red or pink discoloration in the kraut (Downing and Stamer, 1974; Pederson and Albury, 1969). These high salt levels cause decreased growth of heterofermenters which normally produce carbon dioxide that is important in establishing anaerobiosis in the medium. The
yeasts take advantage of the semi-aerobic medium that results from this decreased growth of the heterofermenters. The 2.25% level of salt is used by most kraut producers. It is generally the concentration where titratable acidities reach the maximum. Once cells have been acclimated to this salt level, the generation times of the microorganisms tend to approach those of cells grown in cabbage juice with no salt added (Stamer et al., 1971). At the 2.25% salt level, a firm, crisp texture, bright color, and clean acid flavor are produced in the sauerkraut (Pederson, 1946).

Influence of Temperature

Temperature also plays an important role in influencing the succession of the microbial species involved in the sauerkraut fermentation. The optimum temperature for fermentation is approximately 18°C. At this temperature a final titratable acidity of 1.7% to 2.3%, expressed as lactic acid, will be attained. The final ratio of acetic to lactic acid will be about 1 to 4. At a temperature of 23°C the fermentation rate will be greater and a titratable acidity of 1.0% to 1.5% lactic acid may be attained in 8 to 10 days (Pederson and Albury, 1969). At 32°C, fermentation may occur very rapidly and in 8 to 10 days, an acidity of 1.8% to 2.0% lactic acid may be attained. Most of this acid will be lactic acid produced by the homofermentative bacteria, Lactobacillus plantarum and Pediococcus cerevisiae.
(Pederson and Albury, 1969). The problem with fermentation at high temperatures is that the flavor will be inferior due to the reduced growth of the heterofermenters which produce flavor compounds. Also, at high temperatures, the kraut will darken readily and must be processed immediately after fermentation to provide the longest possible shelf life. At a temperature of 7.5°C, the fermentation proceeds very slowly. It may take one month for an acidity of 0.8% to 0.9% to be attained, and the kraut may not be completely fermented for 6 months.

Pederson (1956) reported that some processors have heated buildings while others do not. If the tanks are filled in warm weather, heat is not needed in the factories. He found that fermentation rates were similar in heated and unheated buildings if the tanks were filled in warm weather. If the cabbage was harvested and packed in cold weather however, the shredded or chopped product needed to be heated slightly to encourage the initial phase of normal fermentation. In this phase, the growth products of the lactic organisms are necessary to inhibit the Gram-negative microorganisms which could grow at the lower temperatures.

Pederson (1956) reported an inverse relationship between the atmospheric temperature of the day before the vats were filled and the rate of fermentation. This may be due to the fact that the cabbage is usually present in the
plant prior to filling of the vat and becomes acclimated to the indoor temperature of the plant.

2. USE OF SALT SUBSTITUTES

A. Sodium Chloride in the Diet

Sodium chloride is an essential part of the human diet. The sodium ion is required in the maintenance of blood pressure and blood volume in the body. It also plays an important role in the regulation of cellular and body fluids. The exact amount of sodium required by the average adult is unknown. Daily requirements are estimated at 200 mg sodium per day, but the total daily intake of sodium in the diet of the North American consumer is approximately 3,900-4,700 mg (IFT, 1980). This is about 20 times the daily need. Dahl (1958) reported estimated daily requirements of sodium chloride ranging from 2 g to 15 g per day.

Excessive sodium intake is a crucial factor in the development of essential hypertension and other health problems (Dahl, 1958 and 1972; Frank and Mickelson, 1969; Haddy, 1980). Persons with medical histories of edema, congestive heart failure, cirrhosis of the liver, or hypertension, should be on sodium-reduced or restricted diets (Frank and Mickelson, 1969). It is also recommended that normal healthy persons reduce their sodium chloride intake to less than 2 g per day to prevent the development of essential hypertension (Haddy, 1980). The Food and
Nutrition Board of the National Academy of Sciences - National Research Council has stated that 1,100 to 3,300 mg of sodium per day are considered safe and adequate amounts for healthy adults (Anon., 1982; USDA, 1980).

Salt and other sodium additives play an important role in many food processing applications. Sodium chloride may be used to alter the environment of some foods such as meats, cheeses, sauerkraut, pickles, and other fermented products. It inhibits the growth of undesirable microorganisms. Salt may be used as a flavoring agent as well as a preservative. It may also be used to control texture and moisture level in some foods. Canned vegetables, meats, bakery products, medications, and even drinking water may contribute to daily sodium intake.

B. Sodium Chloride-Potassium Chloride Mixtures

The addition of salt to foods is a learned habit that is developed in many people starting at a very early age. It is also a very difficult habit to break. Most people desire a certain "salty" quality for many of the foods they consume. Many replacements for table salt have been tested. However, most are based on potassium chloride which has a bitter aftertaste. To quell this bitterness, potassium chloride has often been mixed with citric acid, ammonium chloride, or spices (Frank and Mickelson, 1969). These
mixtures, however, do not give the same desirable flavor as sodium chloride.

A possible substitute for table salt is a mixture composed of equal parts of potassium chloride and sodium chloride. According to Frank and Mickelson (1969), the physical properties of potassium chloride make it ideal to mix with sodium chloride. The mixtures are visually indistinguishable from table salt. Both salts are colorless, transparent, and have cubic crystals with similar refractive indices. Both are obtainable in similar particle sizes. Their specific gravities, NaCl-2.16 and KCl-1.99, are such that they will not separate. Both are water soluble, and their critical humidities, NaCl-76% and KCl-86% at 25°C, are such that they can be protected by the same anti-caking agents.

Potassium is a normal and essential dietary constituent. Increasing potassium intake by using a salt mixture does not exceed the recommended levels of potassium in the diet. In certain types of drug therapy, potassium may be lost. These mixtures may be helpful to persons undergoing this type of therapy. Some researchers have found that increasing potassium in the diet may help counteract hypertension and reduce blood pressure in some individuals (Frank and Mickelson, 1969; IFT, 1980).

Kincaid et al. (1975) conducted sensory evaluation studies using a Magnitude Estimation scale with a 1% sodium
chloride solution as a standard. This amount is typically found in recipes, such as rice dishes. This standard solution was compared to solutions of 0.5, 1.0, 1.5, and 2.0% Morton Lite Salt\textsuperscript{R} Mixture. Morton (1981) describes this mixture as a blend of equal parts of sodium chloride and potassium chloride that provides a degree of saltiness similar to common table salt. The saline taste of sodium chloride masks the typical bitter aftertaste of potassium chloride. Kincaid et al. (1975) found that a solution of about 1.2% Lite Salt tasted as salty as the 1.0% table salt solution. They concluded that by using Lite Salt on food to achieve the taste equivalent of table salt, one can consume approximately 41% less sodium in the diet. A 1:1 mixture of NaCl:KCl contains about 19.65% sodium and 26.20% potassium (Frank and Mickelson, 1969).

Morton (1983) reported tests with Lite Salt in foods such as bread, cheese, canned vegetables, potato chips, crackers, pickles, and sauerkraut. All sensory evaluation flavor scores for table salt- and Lite Salt-treated products showed no significant differences between the two when treated at equivalent levels.

In tests with sauerkraut, panelists rated the kraut prepared with Lite Salt at 5.2 compared to that prepared with sodium chloride at 5.5 on a scale ranging from 1=extremely dislike to 9=extremely like. The lower ionic strength of Lite Salt in the sauerkraut brine resulted in
higher levels of lactic acid production giving a slightly more tart, but not disagreeable, taste to the kraut.
CHAPTER III
MATERIALS AND METHODS

1. PREPARATION OF CABBAGE

Approximately 150 lbs of fresh green cabbage were obtained from a local wholesaler. After the outer leaves were removed, the cabbage heads were rinsed in cold water and quartered. The cores were removed before the cabbage was chopped with a Hobart food preparer. The chopped cabbage was placed in food-grade plastic containers and weighed. Each container was filled with approximately 12 lbs of cabbage.

Three types of salts were used as treatments. Three containers of cabbage were treated with sodium chloride, three with potassium chloride, and three with Morton Lite Salt®, a mixture of equal parts of sodium chloride and potassium chloride. Each of the salts were added to the containers of cabbage at the 2.25% w/w level and thoroughly mixed by hand.

2. FERMENTATION PROCEDURE

The containers of cabbage were fitted with perforated plexiglass plates that rested on the surface of the cabbage. Containers of water were placed on top of the plexiglass as weights that submerged the cabbage (and plexiglass) in the brine formed by the addition of the salts. Plastic film was
used to cover the containers and weights to exclude debris and reduce oxygen levels at the surface of the fermenting cabbage. The containers were placed in Room 6, McLeod Hall, where the temperature was continuously maintained at 20-21°C for the entire 30 days of the fermentation process.

3. SAMPLE COLLECTION

The plexiglass plates were perforated with holes that would accommodate sterile disposable 10 ml pipets for sample collection. The samples were immediately transferred to sterile covered flasks where aliquots could be aseptically removed for testing. The plastic film was replaced on the containers after sample collection. Samples were obtained on days 0, 1, 2, 3, 4, 6, 9, 12, 15, 20, 25, and 30 of the fermentation period.

4. MICROBIOLOGICAL ANALYSIS

Total plate counts were obtained by plating appropriate sample dilutions on Plate Count Agar (PCA) and incubating at 32°C for 48 hours. Counts of lactic acid-producing organisms were obtained by plating appropriate dilutions on Lactobacilli MRS Agar (MRS) and incubating at 32°C for 48 hours. Potato Dextrose Agar (PDA), acidified to an approximate pH of 3.5, was used to obtain counts of yeasts and molds. These plates were incubated at 21°C for 5 days (Speck, 1976).
5. CHEMICAL ANALYSIS

A. Titratable Acidity

Titratable acidity, expressed as per cent lactic acid, was determined during the fermentation period on sauerkraut juice samples. The samples were titrated to a phenolphthalein endpoint of approximately pH 8.1 with standardized 0.1 N sodium hydroxide. A Fisher Accumet pH meter, Model 600, was used to check the endpoint on random samples. Titratable acidity was calculated using the formula:

\[
\% \text{ lactic acid} = \frac{\text{ml NaOH} \times \text{normality NaOH} \times 0.09}{9 \text{ ml sample}} \times 100
\]

B. Juice Evaluation by HPLC

A Waters HPLC instrument, Model 6000A solvent delivery system, with Model U6K injector was used for juice analysis. A Lambda-Max Model LC Spectrophotometer detector was used with a wavelength setting of 210 nm and a range setting of 0.05. A Shimadzu Chromatopac C-R2AX integrator was used to collect information and calculate peak areas. A 1.1% v/v acetic acid solution and a 1.5% v/v lactic acid solution were prepared as standard solutions. Sauerkraut juice samples, with titratable acidities of 1.5%, were obtained from the final products and diluted with equal portions of 0.05 M phosphoric acid adjusted to pH 2.5. These samples were then filtered using ACRO LC13 0.45 micron filters. A
Waters u-Bondapak (Trademark) Phenyl column, P/N 27198, was used with a 0.05 M sulfuric acid solvent. Ten-microliter samples were injected using a Hamilton microliter syringe #802. The solvent flow rate was set at 1.2 ml/min.

C. Sodium/Potassium Determination

Total amounts of sodium and potassium in the final sauerkraut products were determined using a Perkin-Elmer Model 5000 Atomic Absorption Spectrophotometer. The atomic emission mode was utilized. Air-acetylene flames were used with a 5-cm burner head. Conditions for potassium determinations included a 1:500 dilution of sample, 766.5 nm wavelength, and a slit width of 0.4 nm. Conditions for sodium determinations included sample dilutions of 1:100 and 1:2000, a wavelength of 589.0 nm, and a 0.4 nm slit width.

6. SAMPLE STORAGE AFTER FERMENTATION

Drained sauerkraut samples were canned and subjected to thermal processing as the individual treatments achieved titratable acidities equivalent to 1.5% lactic acid. Samples were placed in 303 x 406 cans and boiling water was added before the cans were closed. The cans were processed in McLeod Hall using the still retort as a water bath. The processing time was 25 minutes at 100°C. The cans of sauerkraut were cooled and stored at room temperature until needed for sensory evaluation. Sauerkraut juice samples for
HPLC acid analysis and sodium/potassium determinations were frozen after fermentation to 1.5% lactic acid without being thermally processed.

7. SENSORY EVALUATION

Acceptance or preference testing (Larmond, 1977) of the three sauerkraut treatments was accomplished by use of an untrained consumer-type panel. Fifty-two panelists were given samples of all three treatments, coded with 3-digit random number codes and served at room temperature, and asked to rate these samples using an eight-point hedonic scale ranging from 8=like extremely to 1=dislike extremely. They were also asked to specify which sample they preferred and to state a reason for their preference. An example of the score sheet is shown in Figure 1.

8. EXPERIMENTAL DESIGN

The completely random design was used for the arrangement of the experiment. Microbiological, chemical, and sensory data were analyzed by Analysis of Variance (ANOVA) using the General Linear Model (GLM) procedure. Differences among means were determined by Duncan's Multiple Range test.
Score Sheet

NAME ____________________________ DATE ____________________________

PRODUCT ____________________________

Taste these samples, rinsing your mouth with water between samples, and check how much you like or dislike each one.

<table>
<thead>
<tr>
<th>Code</th>
<th>Code</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>like extremely</td>
<td>like extremely</td>
<td>like extremely</td>
</tr>
<tr>
<td>like very much</td>
<td>like very much</td>
<td>like very much</td>
</tr>
<tr>
<td>like moderately</td>
<td>like moderately</td>
<td>like moderately</td>
</tr>
<tr>
<td>like slightly</td>
<td>like slightly</td>
<td>like slightly</td>
</tr>
<tr>
<td>dislike slightly</td>
<td>dislike slightly</td>
<td>dislike slightly</td>
</tr>
<tr>
<td>dislike moderately</td>
<td>dislike moderately</td>
<td>dislike moderately</td>
</tr>
<tr>
<td>dislike very much</td>
<td>dislike very much</td>
<td>dislike very much</td>
</tr>
<tr>
<td>dislike extremely</td>
<td>dislike extremely</td>
<td>dislike extremely</td>
</tr>
</tbody>
</table>

Which of the three samples did you like best? Code __________
Why? ___________________________________________________________
Comments: _______________________________________________________  

Figure 1. Sensory evaluation score sheet for sauerkraut.
CHAPTER IV

RESULTS AND DISCUSSION

1. MICROBIOLOGICAL ANALYSIS

The fermentation of the cabbage into sauerkraut was monitored during a 30-day period utilizing the counts of lactic acid-producing microorganisms growing on Lactobacilli MRS Agar (MRS) and total counts of microorganisms growing on Plate Count Agar (PCA). Isolation of microorganisms during preliminary studies showed the typical sequence of lactic acid-producing microorganisms throughout the fermentations. Mean total and lactic microbial counts for all treatments are shown in Figure 2. Mean counts of both total and lactic acid-producing microflora peaked on day 2 of the fermentation period at $2.7 \times 10^8$ cfu/ml and approximately $3.0 \times 10^8$ cfu/ml, respectively. Mean counts on MRS then decreased until the 9th day of the fermentation when they reached a low point of about $3.8 \times 10^7$ cfu/ml. Counts then began to increase steadily until the 15th day, when they peaked again at $1.1 \times 10^8$ cfu/ml, and then began to decrease until the end of the fermentation period (Figure 2). These peak counts and fermentation patterns are similar to results obtained by Parmele et al. (1927), Pederson (1930), Pederson and Albury (1969), and Stamer (1975).

Mean microbial counts on PCA and MRS for the sodium treatments were significantly lower ($P<0.01$), $6.6 \times 10^7$
Figure 2. Average microbial counts on MRS and PCA over 30 days of sauerkraut fermentation period.
cfu/ml, than the mean counts for the potassium chloride and Lite Salt treatments, $1.1 \times 10^8$ and $9.8 \times 10^7$ cfu/ml, respectively (Table 1). For the sodium chloride treatments, counts tended to remain lower and more constant on both MRS and PCA, than do the counts for the potassium chloride and Lite Salt treatments (Figures 3 and 4). This was probably due to the greater ionic strength of the sodium chloride in the brine. This results in a less favorable medium for growth of all types of microorganisms. The potassium chloride and the Lite Salt treatments tend to lower the ionic strength of the brine, allowing for greater microbial growth.

The potassium chloride treatments averaged higher counts on both MRS and PCA from day 3 through day 15 (Figures 3 and 4). These counts dropped more rapidly than those for either the Lite Salt or sodium chloride treatments. By day 25, the average potassium chloride treatment counts were lower than counts for the other two salt treatments. This was most likely due to the faster reduction of sugars and other nutrients in the sauerkraut and the faster accumulation of lactic acid end products from the rapid growth of the microorganisms.

Statistical analysis showed that there was a significant replication effect ($P<0.01$) for microbial counts on both PCA and MRS (Table 1). In this study, this effect was not relevant due to the fact that we were not dealing with
TABLE 1. F-Ratios and Error Mean Squares for Total and Lactic Microbial Counts of Sauerkraut

<table>
<thead>
<tr>
<th>Source</th>
<th>D.F.</th>
<th>PCA</th>
<th>MRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>107</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>A. Salt</td>
<td>2</td>
<td>8.96**</td>
<td>16.23**</td>
</tr>
<tr>
<td>B. Day</td>
<td>11</td>
<td>30.63**</td>
<td>68.84**</td>
</tr>
<tr>
<td>C. Replication</td>
<td>2</td>
<td>5.55**</td>
<td>10.52**</td>
</tr>
<tr>
<td>A x B</td>
<td>22</td>
<td>1.14&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>1.50&lt;sup&gt;NS&lt;/sup&gt;</td>
</tr>
<tr>
<td>A x C</td>
<td>4</td>
<td>1.06&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.90&lt;sup&gt;NS&lt;/sup&gt;</td>
</tr>
<tr>
<td>B x C</td>
<td>22</td>
<td>1.03&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>2.44**</td>
</tr>
<tr>
<td>Residual Error</td>
<td>44</td>
<td>1.91 x 10&lt;sup&gt;15&lt;/sup&gt;</td>
<td>1.02 x 10&lt;sup&gt;15&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*Significant at 0.05 level.
**Significant at 0.01 level.
<sup>NS</sup> Not significant at the 0.05 level.
Figure 3. Average treatment microbial counts on PCA over 30 days of sauerkraut fermentation period.
Figure 4. Average treatment microbial counts on MRS over 30 days of sauerkraut fermentation period.
true replications. The experiment was composed of three treatments with three "batches" of each treatment. Each of these nine fermentations was begun with the same amount of cabbage, but not necessarily with the same amount of microflora. The number of microorganisms present on the cabbage differed from head to head and throughout various locations within the individual cabbage heads. It was not possible to obtain a completely homogeneous mixture that would allow each container to begin with exactly the same amount of microflora. The sauerkraut fermentation is a natural fermentation and it is not possible to control the initial microbial populations. These initial populations influence the growth and counts of the various microorganisms throughout the fermentation period.

Yeast and mold growth was monitored by counting colonies growing on acidified Potato Dextrose Agar (PDA). The mean number of yeast and mold colonies from the sodium chloride treatments, $4.7 \times 10^5$ cfu/ml, differed significantly ($P<0.01$) from the mean counts of the potassium chloride, $1.3 \times 10^5$ cfu/ml, and Lite Salt treatments, $1.2 \times 10^5$ cfu/ml (Table 2). The yeast and mold growth was also observed to be the greatest on the surface of the sodium chloride treatments. These higher counts may be an indication of possible spoilage problems due to the presence of an aerobic environment at the surface of the brine. The counts may not accurately reflect amount of mold growth because growth
### TABLE 2. F-Ratios and Error Mean Square for Yeast and Mold Counts of Sauerkraut

<table>
<thead>
<tr>
<th>Source</th>
<th>D.F.</th>
<th>F-Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>53</td>
<td>--</td>
</tr>
<tr>
<td>A. Salt</td>
<td>2</td>
<td>9.15**</td>
</tr>
<tr>
<td>B. Day</td>
<td>5</td>
<td>4.25**</td>
</tr>
<tr>
<td>C. Replication</td>
<td>2</td>
<td>0.88NS</td>
</tr>
<tr>
<td>A x B</td>
<td>10</td>
<td>2.18NS</td>
</tr>
<tr>
<td>A x C</td>
<td>4</td>
<td>6.21*</td>
</tr>
<tr>
<td>B x C</td>
<td>10</td>
<td>1.09NS</td>
</tr>
<tr>
<td>Residual Error</td>
<td>20</td>
<td>7.57 x 10^10</td>
</tr>
</tbody>
</table>

*Significant at 0.05 level.
**Significant at 0.01 level.
NS Not significant at the 0.05 level.
occurred on the surface of the brine and samples were taken at the sauerkraut surface within the brine.

2. CHEMICAL ANALYSES

A. Titratable Acidity

The mean titratable acidity values differed significantly (P<0.01) among all three treatments (Table 3). The potassium chloride treatments had the highest mean value, 0.73, followed by the Lite Salt treatments, 0.67, and the sodium chloride treatments with the lowest mean value, 0.60. In all three treatments, titratable acidity increased throughout the fermentation period. It is the rapid acid production along with carbon dioxide production that inhibits the growth of undesirable spoilage microorganisms. The potassium chloride treatments exhibited the most rapid rise in acidity, followed by the Lite Salt treatments, with the sodium chloride treatments requiring the greatest amount of time to reach maximum acidity (Figure 5). On day 30, the potassium chloride treatments averaged a titratable acidity of 1.37% with a range of 1.22 to 1.56. The Lite Salt treatments averaged 1.30% lactic acid with a range of 1.18 to 1.39. The average titratable acidity of the sodium chloride treatments on day 30 was 1.11% with a range of 0.89 to 1.33.

Figure 6 shows the average treatment daily rate of acid production. This data follows the pattern of mean microbial
**TABLE 3.** F-Ratios and Error Mean Square for Titratable Acidity Values of Sauerkraut

<table>
<thead>
<tr>
<th>Source</th>
<th>D.F.</th>
<th>F-Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>107</td>
<td>--</td>
</tr>
<tr>
<td>A. Salt</td>
<td>2</td>
<td>17.61**</td>
</tr>
<tr>
<td>B. Day</td>
<td>11</td>
<td>154.20**</td>
</tr>
<tr>
<td>C. Replication</td>
<td>2</td>
<td>0.32^NS</td>
</tr>
<tr>
<td>A x B</td>
<td>22</td>
<td>1.06^NS</td>
</tr>
<tr>
<td>A x C</td>
<td>4</td>
<td>3.30^*</td>
</tr>
<tr>
<td>B x C</td>
<td>22</td>
<td>0.23^NS</td>
</tr>
<tr>
<td>Residual Error</td>
<td>44</td>
<td>0.0090</td>
</tr>
</tbody>
</table>

*Significant at 0.05 level

**Significant at 0.01 level

^NS Not Significant at the 0.05 level.
Figure 5. Average treatment titratable acidity values over 30 days of sauerkraut fermentation period.
Figure 6. Average treatment daily rates of acid production.
counts on MRS with acid production peaking on day 2 which coincides with the maximum lactic counts on day 2.

B. HPLC Analysis

The HPLC analyses produced chromatograms with 5 peaks common to each sample. Comparison with chromatograms of standards revealed the inability of our system to separate the acids, lactic and acetic. However, Analysis of Variance for peaks 1, 2, 3, 4, and 5 showed no significant treatment or replication effect (Table 4). This showed that there was no significant difference in sauerkraut juice components among the three treatments.

C. Sodium/Potassium Determination

Potassium and sodium levels were analyzed to determine potential reduction in sodium content of sauerkraut. Mean sodium and potassium levels were found to be significantly different (P<0.01) among all three treatments. (Table 5). Our results showed that 100 g of the sauerkraut prepared with sodium chloride contained 998 mg of sodium. Commercially canned sauerkraut was reported to contain approximately 661 mg of sodium per 100 g of kraut (USDA, 1980).

3. SENSORY EVALUATION

Sensory evaluation flavor scores from 52 untrained panelists showed a significant treatment effect (P<0.01) in
TABLE 4. F-Ratios and Error Mean Squares for HPLC Acid Analyses of Sauerkraut

<table>
<thead>
<tr>
<th>Source</th>
<th>D.F.</th>
<th>Peak 1</th>
<th>Peak 2</th>
<th>Peak 3</th>
<th>Peak 4</th>
<th>Peak 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>5</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Salt</td>
<td>2</td>
<td>0.08&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>15.99&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.09&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.01&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.37&lt;sup&gt;NS&lt;/sup&gt;</td>
</tr>
<tr>
<td>Replication</td>
<td>2</td>
<td>0.34&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>1.87&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.11&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.24&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.15&lt;sup&gt;NS&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Mean Squares

| Error        | 1    | 1410.0 | 3.7/21.7<sup>2</sup> | 128.5  | 62.8   | 16.6   |

<sup>1</sup>One less observation was used in analysis of peak 2 values than for peaks 1, 3, 4, and 5.

<sup>2</sup>Peak 2 ANOVA was calculated separately for treatment and for replication with error D.F.=2 for each calculation, providing 2 mean square values.

<sup>NS</sup>Not significant at 0.05 level.
TABLE 5. Means for the Sodium/Potassium Determinations

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sodium (mg/100g)</th>
<th>Potassium (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium chloride</td>
<td>11.45 ± 1.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1788.3 ± 79.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Morton Lite Salt&lt;sup&gt;R&lt;/sup&gt;</td>
<td>572.0 ± 25.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>915.0 ± 28.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>998.0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.0&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a-c</sup>Means in the same column followed by different letters are different at the 0.01 level of significance.
Analysis of Variance. Duncan's Multiple Range test showed no significant difference in flavor preference between the sodium chloride and Lite Salt treatments. Both of these were rated between 5=like slightly and 6=like moderately. The potassium chloride treatment was rated significantly lower than the other two with a value of 4=dislike slightly (Table 6).

Panelists described the sauerkraut prepared with Lite Salt as having a "moderately acidic, smooth, pleasant taste" that was "similar" to the taste of the kraut prepared with sodium chloride, which was described as having a "good acid taste with enough salt to complement." The kraut prepared with potassium chloride was described as having a "bitter, metallic aftertaste."
TABLE 6. Means for the Sensory Evaluation

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium chloride</td>
<td>4.19 ± 1.71a</td>
</tr>
<tr>
<td>Morton Lite Salt</td>
<td>5.60 ± 1.57b</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>5.79 ± 1.29b</td>
</tr>
</tbody>
</table>

\(^{14}=\text{dislike slightly}; 5=\text{like slightly}; 6=\text{like moderately.}\)

\(^{a-b}=\text{Means followed by different letters are different at the 0.01 level of significance.}\)
CHAPTER V

SUMMARY AND CONCLUSIONS

This study was undertaken to evaluate the use of potassium chloride as a partial or complete replacement for sodium chloride in the preparation of sauerkraut.

Nine containers of chopped cabbage were prepared and three were treated with sodium chloride, three with potassium chloride, and three with Morton Lite Salt®. These mixtures were allowed to naturally ferment for 30 days. Over the course of the fermentation period, total microbial counts, lactic acid producing-bacterial counts, yeast and mold counts, and titratable acidities were monitored at designated intervals.

Total and lactic microbial counts for the potassium chloride and Lite Salt treatments were found to be higher than counts for the sodium chloride treatments. This is due to the lower ionic strength of the potassium chloride in the brine which allows for greater microbial growth and therefore, greater lactic acid production as was evidenced by the higher titratable acidity values of the potassium chloride and Lite Salt treatments. Krauts prepared with these salts reached an optimum titratable acidity faster than did krauts prepared with sodium chloride. This could be beneficial to those who prepare sauerkraut at home.

The greater lactic bacterial growth lead to a faster
accumulation of carbon dioxide and lactic acid which, along with the salt, aids in inhibiting growth of undesirable microorganisms. These facts show the microbiological safety of the sauerkraut products prepared with some amount of potassium chloride.

The finished sauerkraut was processed and stored for further chemical and sensory evaluation. Sauerkraut juice was evaluated using an HPLC instrument. No significant differences were found in the sauerkraut juice components of all three treatments. Further study is necessary for complete identification and quantification of all peaks revealed by HPLC analysis.

The amounts of sodium and potassium present in the finished sauerkraut products were determined by atomic absorption spectrophotometric analyses. Sodium reduction in the kraut prepared with potassium chloride is about 98%. Sodium reduction using Lite Salt is about 40-45%. Morton (1983) reports potential sodium reductions of 48% in sauerkraut produced with Lite Salt. Reductions of this kind could benefit those on sodium-reduced diets.

Sensory evaluation was accomplished using an untrained consumer-type panel. Sauerkraut prepared with Lite Salt compared favorably to the kraut prepared with sodium chloride. Average results scored both of these between "like moderately" and "like slightly." The kraut prepared with Lite Salt did not have a bitter aftertaste because the
acid flavor masked the undesirable bitterness. The kraut prepared with potassium chloride was rated lower than the other two at "dislike slightly." This kraut could be improved by the addition of other flavor ingredients, such as peppers, onions, or spices, to mask its bitter after-taste. Other salt mixtures with higher ratios of potassium chloride to sodium chloride should be tested to determine at exactly what level of potassium chloride the acid can no longer mask the bitter flavor.

In this study it was shown that potassium chloride can be used as at least a partial replacement for sodium chloride in the fermentation of sauerkraut. Use of Lite Salt provides a microbiologically and chemically safe product that is not only palatable but compares favorably to kraut prepared with sodium chloride and provides a substantial amount of sodium reduction for consumers wanting to reduce their intake of sodium.

The USDA grade standards (7 CFR 52.2963) specify that sauerkraut must contain a minimum of 1.3% salt and a maximum of 2.5% salt expressed as sodium chloride (Code of Federal Regulations, 1982). Unless these standards are changed, potassium chloride can not legally be used in commercial sauerkraut production.
BIBLIOGRAPHY


APPENDIX
Figure A1. Average treatment log microbial counts on PCA over 30 days of sauerkraut fermentation period.
Figure A2. Average treatment log microbial counts on MRS over 30 days of sauerkraut fermentation period.
VITA

Karen Lenise Guy Jones was born in Cleveland, Tennessee on May 23, 1962, to China Ruth and Myles Marvin Guy. She graduated as Valedictorian of Cleveland High School in May, 1980. The author attended the University of Tennessee at Chattanooga before transferring to the University of Tennessee at Knoxville for her Junior and Senior years. Here she received the Bachelor of Science degree with a major in Food Technology and Science, graduating with highest honors, in June, 1984. During her years as an undergraduate student, the author worked as a laboratory research assistant in the department of Food Technology and Science. She entered the Graduate School at the University of Tennessee at Knoxville in September, 1984, and also worked as a laboratory research assistant in Food Technology during her 2 years in Graduate School. The author was married to Dennis Wilson Jones on September 1, 1984.

As a member of the Institute of Food Technologists, the author served as Chairman of the National Student Association of IFT. She is also a member of Alpha Lambda Delta, Phi Eta Sigma, Alpha Zeta, Gamma Sigma Delta, Phi Tau Sigma, and Phi Kappa Phi Honor Societies.