PERFORMANCE VARIABILITIES OF INSULATED BULK FOOD CARRIERS WITH RESPECT TO HEAT RETENTION AND MICROBIAL QUALITY OF MASHED POTATOES

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The growth in sales for the total foodservice industry rose from $178.6 billion in 1986 to 203.1 billion in 1988. The forecasted total foodservice sales for 1989 is projected as $215.7 billion (Bartlett, 1989). "The average family's weekly expenditure on food away from home is at an all-time high of $31.72. Approximately 33% of the consumers surveyed by Restaurants & Institutions indicate they will eat out more frequently in 1989" (Bartlett, 1989). Eating away from home has become an integral part at American food expenditures.

With increased food-away-from-home, consumers are becoming more quality conscious. They are confronted with the following foodservice issues. Does the food maintain enough nutrients during production and pre-service procedures? Is the food safe to be consumed? Are the food tasty? Are the food served at an appropriate eating temperature? Lastly, is the food held within safe and acceptable temperature ranges?

There are four types of quantity foodservice systems: (1) conventional, (2) commissary, (3) ready prepared, and (4) assembly/service systems (Spears & Vaden, 1985). The ultimate goal of these foodservice systems is to produce entrees within a quality assurance environment and to serve the food products within a safe temperature range. In a conventional and/or commissary foodservice systems, meals prepared in a central production area are usually held hot for several hours prior to service. In a meals-on-wheels systems, meals are often held in insulated food carriers for several hours during transportation and then served. In hospital foodservice, patients' trays must be transported from kitchen to various nursing units. Although the statement "keep hot food hot and cold food cold" is familiar to foodservice managers and employees in hospital foodservices, it is possible that patients' trays are served in a "temperature danger range" from 45^0F to 140^0F because of ineffective temperature control during transportation process.

Factors such as the length of holding time, moisture, temperature, and the temperature retention efficiency of food carriers will influence the nutrient retention, sensory quality, and microbial quality of food products. A recent survey of 75 foodservice operators in three commercial foodservice segments (fast food, full service, and hotel/motel) indicated that the operators wanted to invest their money in effective and reliable equipment (Wolson, 1986). The efficiency of food holding equipment in temperature retention will be very important for assuring food quality in future foodservice systems.

An abundance of literature on foodservice systems focuses on the nutrient retention, microbial safety, and sensory quality of food products. Limited data was not available on the performance of insulated bulk food carriers in different sizes and at various percent capacity fills. In this study, comparsions were made in the temperature variance and in the microbial count increase in reconstituted mashed potatoes held hot in three sizes of insulated bulk food carriers. The parameters compared were (1) heat retaining performance in the size and the percent capacity fill of insulated food carriers and (2) microbial count increase in mashed potatoes held hot in insulated food carriers from 0 to 3 hours.

Purpose and Objectives

The purpose of this study was to compare the performance variability of three sizes of food carriers with respect to heat retention and microbial safety of mashed potatoes. The specific objectives of this study were:

1. To assess the heat retaining performance in the sizes of insulated bulk food carriers at 100 percent fill.
2. To assess the heat retaining performance of insulated bulk food carriers at various percent capacity fills (i.e. 2" pan at 100% fill, 4" pan at 50% fill, and 6" pan at 33.3% fill).

3. To assess the heat retaining performance at 3 positions (the center, the midpoint, and the corner) of 2", 4", and 6" food carriers at various percent capacity fills.
4. To assess the microbial count increase in mashed potatoes held hot in various insulated bulk food carriers from 0 to 3 hours.

Hypotheses

The hypotheses postulated for the study were:

1. There will be no significant difference in the heat retaining performance among 2", 4", and 6" food carriers at 100 percent fill.
2. There will be no significant difference in the heat retaining performance among 2", 4", and 6" food carriers at various percent capacity fills (i.e. 2" pan at 100% fill, 4" pan at 50% fill, and 6" pan at 33.3% fill).
3. There will be no significant difference in the heat retaining performance among the center, the midpoint, and the corner of 2", 4", and 6" food carriers.
4. There will be no significant difference in the microbial count increase in mashed potatoes held hot in various insulated bulk food carriers from 0 to 3 hours.

Assumptions and Limitations of the Study

The assumptions formulated for this study included:

1. Room temperature and humidity were the same during the time that the experiments were carried out;
2. The microbial counts in the instant mashed potato powders were the same in all of the cans.

This study was limited by the following factors:

1. Two brands of insulated bulk food carriers had to be used for this study;
2. The study was conducted using only one type of food product prepared from dehydrated potato powders.

Definition of Terms

The following definitions were accepted for the study:

1. Foodservice systems. A facility where quantities of food are routinely provided for individual consumption and service. Food may be totally prepared, totally purchased, or a combination of purchased and prepared. This facility includes any place regardless of whether consumption is on or off the premises (Unklesbay, Maxcy, Knickrehm, Stevenson, Cremer, & Matthews, 1977).
2. Commissary foodservice systems. Foods are generally purchased in large quantities with little or no processing and held after delivery at the facility under appropriate environmental conditions in frozen,

refrigerated, or dry storage. Most menu items in commissary systems are processed completely in a central facility (Spears & Vaden, 1985).

3. <u>Conventional foodservice systems.</u> Foods are purchased for an individual operation in various stages of preparation, but all production is completed and foods are served on the same premises. Following production, foods are held hot or chilled, as appropriate for the menu item, and served as soon as possible. The conventional foodservice system is the type most establishments have traditionally used (Spears & Vaden, 1985).

4. <u>Heat retention.</u> The quality of hot-holding devices to maintain food at temperatures of 140^0F (60^0C) or higher.

5. <u>Microbial quality.</u> The quality is determined by the number of microorganisms or of specific types of microorganisms, as determined by prescribed methods, in a food.

CHAPTER II

REVIEW OF LITERATURE

In this chapter, the literature related to the effects of time and temperature on food quality in cook and then hot-holding foodservice systems was reviewed. Research in the last 40 years on foodservice has demonstrated that time and temperature during hot-holding process clearly affects the nutritional, microbial, and sensory quality of foods prepared under different foodservice systems. In the following sections, the research related to holding time and temperature in terms of (1) nutrient retention during hot-holding process, (2) microbial safety of foods under cook and then hot-holding foodservice systems, (3) sensory quality of foods held hot for different time periods, and (4) hot-holding effectiveness of various foodservice equipments are discussed.

Nutrient Retention During Hot-holding Process

Prior to the 1940s, research efforts were focused on the nutrient content of home made menu items (Halliday & Kahn, 1944). During the 1940s, studies were directed toward the effects of hot-holding upon the nutrient content of menu items prepared in restaurants and institutions.

Ascorbic acid either analyzed separately or with dehydroascorbic acid was the nutrient most frequently investigated, followed by thiamine and riboflavin. In the following sections, research related to the nutrient retention of these vitamins during hot-holding process will be discussed.

Several researches have studied the losses of thiamine and riboflavin. Nightingale (1983) investigated thiamine retention in spaghetti with meat sauce (80 percent beef) under hot-holding conditions. The results indicated that the apparent thiamine retention was 77 percent following 90 minutes of holding at $174^{0}F$ ($79^{0}C$), and 78 percent after holding 3 3/4 hours at $162^{0}F$ ($72^{0}C$) (wet-weight basis). A similar study by the University of Illinois (Klein, Matthews, & Setser, 1984) found that 87 percent thiamine retention (wet-weight basis) after 90 minutes of holding at $149^{0}F$ ($65^{0}C$). Little or no riboflavin losses were observed in this study. Ang, Chang, Frey, and Livingston (1975) evaluated riboflavin retention in pot roast and gravy; there was 82 percent riboflavin retained in the product after conventional foodservice preparation and 3 hours of holding.

Ascorbic acid retention was not evident, however, as compared to thiamine or to riboflavin. Two studies examined the ascorbic acid losses related to the type of food or the type of holding equipment. Daum, Aimone, and Hollister (1943) heated canned and fresh vegetables and then held these vegetables on a steam table to investigate ascorbic acid retention. The results indicated that new potatoes lost the greatest amount of ascorbic acid after holding for 60 minutes. Wood, Collins, Stodola, Burgoin, and Fenton (1946) held cooked cabbage in three different types of holding equipment: a steam counter, a hot-holding cabinet, and a warmer. Cabbage held in the hot-holding cabinet for 12 minutes had the greatest ascorbic acid losses, but the amount of thiamine and riboflavin had no significant change during holding periods.

Others have studied the relationship of ascorbic acid losses, holding time, and holding temperature. Ang et al. (1975) reported that freshly prepared mashed potatoes retained 66 percent ascorbic acid after 1/2 hour of holding and 40 percent after 3 hours of holding. Nightingale (1983) investigated ascorbic acid retention in spaghetti with meat sauce and demonstrated that 59 percent ascorbic acid was retained after 1 1/2 hours hot-holding at 174^0F (79^0C).

All of these studies exhibited the following conclusions: (1) holding time and temperature influenced the nutrient retention in food products during hot-holding process; (2) longer holding time and higher holding temperature resulted greater nutrient losses in all menu items; (3) entree items usually showed better nutrient retention than vegetables; and (4) potatoes were the vegetable having the greatest amount of nutrient losses during hot holding process.

Several recommendations were provided in the various studies. Branion, Roberts, Cameron, and McCready (1947), Gleim, Albury, McCartney, Visnyei, and Fenton (1946), and Heller, Macay, and Lyon (1943) recommended that vegetables be held for the shortest time in order to conserve ascorbic acid. Streightoff et al. (1946) suggested that potatoes be consumed as soon as possible after preparation. Jonsson and Karlstrom (1979) advised that hot food be held at 65^0C (149^0F) or above for no longer than 2 hours.

Microbial Safety of Foods Under Cook/Hold Foodservice Systems

Our world is filled with countless number of microorganisms. Bacteria are the microorganisms which usually cause illness in human. Bacteria needs three things to grow: food, moisture, and temperature (Knight & Kotschevar, 1978). Most bacteria thrive best at the temperatures from 60^0F to 120^0F (15.6^0C to 49^0C) and cease growth at the temperature above 140^0F (60^0C) and at temperatures 45^0F (7.2^0C) or below (Longree & Blaker 1982). During food preparation and holding process, potentially hazardous foods, including milk or milk products, eggs, meats, seafoods, and ingredients, should be heated rapidly to 165^0F (74^0C) or higher throughout before being served or being placed in a hot-food storage facility (USDHEW, 1978). On the other hand, foods plated hot can have a minimum temperature of 140^{0}F (60^{0}C) for microbial safety (USDHEW, 1978).

Nelson (1974) investigated microbial counts on several raw vegetables (i.e. green beans, cabbages, lettuce, etc.) and found resident populations ranging from 10,000 to an excess of 60 million/gm. In cooked food, an abundance of bacteria, the counts significantly over 100/gm or /ml, signifies negligent personal habits, sanitation, or temperature (Ayres, Mundt, & Sandine, 1980). The significance lies not in the numbers imparted, but in their potential for growth with the optimal temperature (60^{0}F to 120^{0}F).

Researchers have studied the relationships among microbial safety, holding time, and holding temperatures. Brown and Twedt (1972) cooked beef roast to an internal temperature of 60^{0}C, cubed, inoculated the beef cubes with _Salmonella_, _staphylococci_, and _C_. _perfringens_, and then incubated the products at 43 to 53^{0}C for 0, 6, 12, 18, and 24 hours. Few _staphylococci_ and _Salmonella_ remained after the beef cubes held at 49^{0}C or at 51^{0}C for 6 hours. Roast beef was also studied by Ockerman and Dowiercial (1982). After cooking, they inoculated beef roasts with _E_. _coli_ and then store the products in a warming oven at 54^{0}C and 60^{0}C for 1, 2, 6, and 12 hours. The results show that _E_. _coli_ is destroyed in less than 6 hours at the 60^{0}C holding temperature. Based on these findings, the authors suggested that roast beef can be safety held at 60^{0}C without posing the threat of foodborne disease hazard.

Snyder, Matthews, and Marth (1983) inoculated B. cereus on the surface of whipped potatoes and then determined the survival of the organism following pre-service holding at 60^0C (140^0F) for 60 minutes. There was little change in the number of B. cereus in whipped potatoes before and after preservice holding. However, because the temperature of the equipment and product under actual operating conditions can both fluctuate, it is recommended that pans be covered, and temperature of menu items be higher than 60^0C when placed into holding units and that equipment temperature be greater than product temperature. Bryan, Bartleson, and Christopherson (1981) analyzed various food handling practices used by Cantonese-style restaurants in the preparation of boiled and fried rice. The results show that the growth of B. cereus could occur when the rice was held at room temperatures. The authors also recommended that cooked rice be held at 60^0C or above to prevent the growth of B. cereus during the hot-holding process.

Al-Obaidy, Klan, and Klein (1983) found that the temperature of spaghetti with meat sauce held on a steam table decreased from 74^0C (165^0F) to 66^0C (151^0F) in approximately 30 minutes and that aerobic plate counts before and after 90 minutes at 66^0C (151^0F) were less than 2,000 microorganisms per gram. Although the plate counts were not dangerously high, the authors indicated that plate counts could evaluate during storage and post-holding contamination. Maxcy (1976) investigating the post-holding contaminants *E. coli*, *Salmonella*, *S. aureus*, and *C. perfringens* found that covering food with a polyethylene film could increase the destruction of surface contaminants. In conventional and commissary foodservice systems, prolonged holding of uncovered cooked foods could increase the potential hazards originating from microbial contaminants.

Sensory Quality of Foods Held Hot for Different Time Intervals

The sensory quality of food indicates consumer response to certain food attributes such as appearance, flavor, texture, and temperature (Klein et al., 1984). All of these attributes are measured and controlled by sensory evaluation which is evaluated by sensory evaluation panels and made by the senses of taste, smell, touch, and hearing when food is eaten (Mastrian, 1985). Generally there are two types of sensory evaluation panels. Highly trained experts evaluate food quality; large consumer panels determine consumer reaction to a product (Mastrian, 1985). In the following sections, research on the effects of time, temperature, type of food, and preferred eating temperature on the sensory quality of food during hot-holding process was discussed.

Previous studies have demonstrated that hot-holding really destroys the sensory quality of food products. However, sensory quality losses through hot-holding can be reduced by proper control of the holding time and the temperature. Benftsson and Dagersbog (1978) demonstrated that more than 2 hours of hot-holding greatly reduced the sensory quality of beef slices and patties in cook and then freeze systems. However, differences noted in the beef products after precooking were not noticeable after 2 hours of hot-holding.

Paulus, Nowak, Zacharios, and Bognav (1978) evaluated the sensory quality of meat entrees, including sauerbraten, chicken fricassee, meat loaf, beef goulash, and fried sausage, and concluded that meat entrees could be kept warm for at least 3 hours without decreasing the sensory quality. However, Brown and Chyuan (1987) investigated the sensory quality of turkey rolls cooked in an institutional electric convection oven to an internal temperature of $77^{0}C$ and then held hot for 0, 60, and 120 minutes. The results indicated that the juice retained in cooked turkey rolls is significantly decreased during hot holding process and that the turkey rolls held hot for 120 minutes have the highest percentage losses. Hill, Baron, Kent, and Glew (1977) investigated the effects of hot-holding on vegetable quality and suggested that cooked vegetables should be consumed immediately and not be held hot for more than 30 minutes.

The type of food is an important factor in food sensory evaluation. According to a series of studies conducted in Europe, the researchers found that increased hot-holding time and hot-holding temperature resulted to an substantial decrease of the sensory quality of potatoes and peas. However, there was no effects on fish and meat products (Jonsson & Karlstrom, 1976; Jonsson & Karlstrom, 1979; Jonsson & Karlstrom, 1980; Jonsson, 1981; Jonsson & Danielsson, 1981; Jonsson & Karlstrom, 1981; Karlstrom, 1982; Lundgren, Karlstrom, and Ljungquist, 1979). Blaker, Newcomer, and Ramsey (1961) and Lundgren et al. (1979) also demonstrated that higher temperature or longer holding periods had seriously affected on potatoes sensory properities, especially their flavor and texture.

Besides holding time, holding temperature, and the type of food, the temperature of food is another important factor in sensory acceptance (Dahl, 1982). Two studies were related to the preferred eating temperatures.

Blaker, Newcomer, and Ramsey (1961) suggested the following preferred temperature ranges for four classes of foods served hot: (1) soup: 145^{0}F to 150^{0}F (63^{0}C to 66^{0}C); (2) potatoes and vegetables: 140^{0}F to 145^{0}F (60^{0}C to 63^{0}C); (3) entrees: 140^{0}F to 145^{0}F (60^{0}C to 63^{0}C); and (4) beverages: 145^{0}F to 150^{0}F (63^{0}C to 66^{0}C). In a study about surgical patients, Thompson and Johnson (1963) indicated a wide range of acceptable temperatures for three types of foods: (1) meat: 100^{0}F to 160^{0}F (38^{0}C to 71^{0}C), (2) potatoes: 115^{0}F to 174^{0}F (46^{0}C to 79^{0}C), and (3) vegetables: 120^{0}F to 174^{0}F (49^{0}C to 79^{0}C). According to these studies, foodservice staff should hold cooked food at a temperature higher than the preferred eating temperatures before serving the food.

Hot-holding Effectiveness of Various Foodservice Equipments

Because most microorganisms thrive best at the temperatures from 60^{0}F to 120^{0}F (15.6^{0}C to 49^{0}C), it is important that foodservice holding equipment can effectively keep hot food above the recommended temperature (74^{0}C/165^{0}F) and maintain cold food at the recommended temperature (7^{0}C/45^{0}F) or below (USDHEW, 1978; Longree, 1980).

In this section, research related to hot-holding effectiveness of various holding equipments was discussed. In large-scale foodservice systems, containers play an important role in bulk food holding or transportation process. Ross (1971) and Shea (1974) demonstrated that preheated foodservice holding equipments had beneficial effects on keeping food temperature during hot-holding periods. If there must be a long time between food preparation and service, Ross (1971) suggested that foodservice staff should hold or transport food with heated containers or with insulated or enclosed food carriers.

Leong and Ebro (1988) assessed the heat retaining capabilities of two types of insulated bulk food carriers holding hot mashed potatoes for 12 hours. The results show that the temperature decline per hour is $3^{0}C$ and that the pre-heating and pre-chilling of the insulated food carriers enhanced temperature sustainability. After 12-hour holding, mashed potatoes became crusting, odorous, dehydrated, discolored, and crumbling.

Hot-holding of food is usually accomplished through the use of a stationary steam table or movable carts. Ross (1971) and Blaker et al. (1961) tested the heat retention of steam tables and concluded that, if food came to the steam table at $160^{0}F$ or higher, steam tables could sufficiently maintain food temperature at $140^{0}F$ or above for at least one hour. Shea (1974) compared the efficiency in three types of insulated food delivery systems (an insulated fiber glass system, an insulated plastic system, and an insulated polyglass system) and then concluded that the insulated fiber glass system had the best heat retention and that the last one was insulated polyglass system.

Anderson (1978) investigated the cooling rates of solid and liquid food samples in a ducted-type forced air convection oven and a microwave oven. Results of this study indicated that the cooling rate of food products was influenced by the types of food, the thermal film used to cover the serviceware, and the types of serviceware.

CHAPTER III

RESEARCH PROCEDURES

This study was conducted to assess the performance variabilities of insulated bulk food carriers with respect to heat retention and microbial safety of mashed potatoes. Three sizes of insulated bulk food carriers holding various capacities of mashed potatoes were studied. The purpose of this chapter is to identify the research design, the materials, and the methods used to test the hypotheses of this study.

Research Design

This study was a repeated measure design and was analyzed as a split-plot with pans as the main plot and with time and loading position in the pan as split units. The P values were computed with the degrees of freedom for the F values modified following Winer (1962) to account for the repeated measures.

A fixed model was used for the experimental design. The treatments were the size, the percent capacity fill, and the position of temperature recording probe in insulated bulk food carriers. There were three sizes of insulated food carriers used for this study: 12"x20"x2", 12"x20"x4", and 12"x20"x6". After holding a same amount of mashed potatoes, the inside pans of these food carriers would be at 100%, 50%, 33.3%, or 66.7% fills.

Repeated measure was designed only for the temperature recording experiments. Temperature was tested at three positions: the center, the midpoint, and the corner (see Figure. 1). The split units were the time intervals used for temperature recording from 1 to 5 hours and for microbial sampling from 0 to 3 hours.

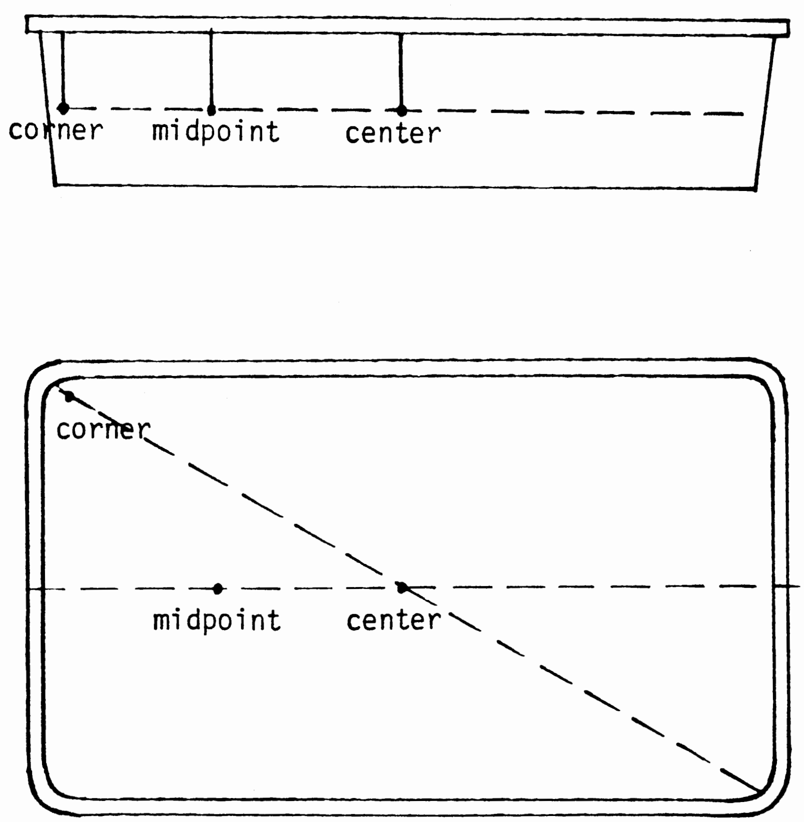

Figure 1. The Arrangement of the Temperature Recording Probes in the Insulated Bulk Food Carriers

The independent variables of this study were the holding time, the pan size, the percent capacity fill, and the position of temperature recording probe. The dependent variables were the temperature and the microbial counts.

Materials and Methods

In the following sections, procedures such as: (1) selection of mashed potato product, (2) selection of insulated bulk food carriers, (3) pre-experimental phase, (4) preparation procedures for reconstituted mashed potatoes, (5) temperature recording, and (6) microbial analysis used in this study are introduced.

Selection of Mashed Potato Product

Mashed potatoes were selected for study for the following reasons:

1. According to the 1987 Menu Census conducted by the Restaurants and Institutions, potatoes were the best-selling side dishes in the U.S. Patrons usually preferred potatoes on every type of foodservice menu, from fast food to fine dining.
2. Potato products are sensitive to heat. It would be a suitable medium to test the temperature retention efficiency of these food carriers.
3. Potato broth has long been used by microbiologists as an ingredient of culture media for stimulating growth of various bacteria, yeasts, and molds

(Talburt and Smith, 1987).

French's dehydrated mashed potato powders, in No. 10 can, was used in this study. The instant mashed potatoes was prepared according to the product instructions showed on the cans (i.e. 3 qt. of water, 2 tsp. of salt, and 1 lb. 6 oz. of mashed potato powders for 1 gallon of reconstituted mashed potatoes, see Appendix). Mashed potato powders, salt, and water were mixed according to the product instruction.

Selection of Insulated Bulk Food Carriers

Two brands of insulated bulk food carriers, Cambro Manufacturing Company and Continental Carlisle Corporation, were available for this study. The interior sizes of these food carriers were 12"x20"x2", 12"x20"x4", and 12"x20"x6". Each food carrier had a polyethylene inside pan for holding food products. The same sizes of plastic pans could match the interior sizes of either Cambro or Continental food carriers. Additionally, there was a vent located in the center of the lid of each food carrier.

In this study, a random number table was used to designate the brand of food carriers. A starting point in a random number table was located and 3 continuous one-digit numbers were selected on the right side of the starting one. An odd number represented Cambro food carriers; an even number represented Continental food carriers. The result of the random selection of food carriers was as follows:

Size	Brand of Food Carrier		
2.5"	Continental	Cambro	Cambro
4"	Continental	Cambro	Continental
6"	Cambro	Continental	Continental

Pre-Experimental Phase

All of the experimental work was conducted in the Home Economics East Building at Oklahoma State University. During the pre-experimental phase, the amounts of mashed potato powders and of salt were weighed with a top loading gram balance, water was boiled in a 20 quart steam jacketed kettle, and the insulated wire thermocouples from the Honeywell multipoint recorder were placed through the vent and positioned for temperature recording.

Preparation Procedures for Reconstituted Mashed Potatoes

Mashed potato powder was mixed in the following procedure:

1. Put salt into a 12 quart Hobart mixer,
2. Measure the amount of boiling water and pour it into the mixer immediately,
3. Start the mixer and pour mashed potato powder into the water gradually,
4. Mix at a low speed for 10 seconds,
5. Continuously mix at a high speed for 30 seconds,

6. Drop the mixed mashed potatoes into a inside pan (immediately after mixture) and put the pan in a preheated steam table,
7. Heat the pan until the central temperature of mashed potatoes reached 170^{0}F (this step took about 20 minutes),
8. Move the pan into a food carrier and ready for temperature recording.

Temperature Recording

The temperature differences of mashed potatoes was recorded with a Honeywell multipoint recorder. The Honeywell multipoint recorder was attached to insulated wire thermocouples. After the pan of mashed potatoes was moved into a food carrier, the insulated wire thermocouples were placed through the pan lid and into three points in mashed potatoes (see Figure 1). The temperature differences were recorded continuously for 5 hours. A total of 52 data entries were collected from each temperature recording position.

Microbial Analysis

Mashed potatoes were prepared as previous procedures in Home Economics East building. Samples (1 gm of mashed potatoes) were randomly taken from the surface layer of reconstituted mashed potatoes at 0 hour (immediately after preparation) and at 1, 2, and 3 hours after holding.

Samples were then delivered to Life Science East building for microbial studies. Microbial analysis was assisted by Dr. Samad and Dr. Grula.

Each sample was diluted with distilled water in the ratio of 1:9. Diluted samples were then incubated at $42^{0}C$ for 22 hours for the plate counts. Standard bacteriological techniques were used to determine the aerobic and the anaerobic plate counts. Trypticase-soy agra (TSA) was used for the aerobic and the anaerobic plate counts. Gram's method, involving treatment with gentian violet, an iodine solution, and alcohol, was used for the classification of bacteria.

Data Analysis

The analysis of variance (ANOVA) procedure of The Statistical Analysis System (SAS) was used for data analysis in this study. The ANOVA procedure is designed to analyze variance for balanced data (that is, data with equal numbers of observations for every combination of the classification factors).

A continuous response variable (Temperature) was measured under experimental conditions identified by classification variables (time and percent capacity fill). The variation in the response is explained as being due to effects in the classification with random error accounting for the remaining variance.

In this study, repeated measure design were conducted only for temperature variance experiments. The null hypotheses were tested by the F values. The level of significance of the test was 0.05.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to evaluate the performance of insulated bulk food carriers in different pan sizes and at various percent capacity fills. It was also determined if the holding time, the pan size, and the percent capacity fill made a difference in the microorganism growth in reconstituted mashed potatoes. Four null hypotheses were postulated, which assumed that the results of the study would reveal no significant differences in the pan size, the percent capacity fill of insulated bulk food carriers, and the holding time of mashed potatoes.

A split-plot design was conducted for data analyses. The time periods for temperature studies were 1, 2, 3, 4, and 5 hours, and the time intervals for microbial sampling were 0, 1, 2, and 3 hours. The treatments were the pan sizes (2", 4", and 6"), the percent capacity fills (100.0%, 66.7%, 50.0%, and 33.3%), and the positions of temperature recording probes (at the center, the midpoint, and the corner of food carriers). Three replications were designed for temperature variance studies; but there were no replication conducted for the microbial experiments.

Results

Comparison of Temperature Variance

Table I exhibits the comparison of temperature variance of 2", 4", and 6" food carriers at 100 percent fill. The results indicated that there were significant differences ($P < 0.05$) in pan size, holding time, and position. No significant difference were found in the the interaction betweem time and pan size and between position and pan size.

After 5 hour holding, the total temperature decreases at the center of 2", 4", and 6" food carriers at 100% fill were as follows: 20.7^{0}C for 2" food carriers, 19.7^{0}C for 4" food carriers, and 10.8^{0}C for 6" food carriers (see Table II). The major temperature variances were found within the first hour of holding (see Figure 2). Within the first hour, 4" food carriers had the largest amount of heat loss (9.1^{0}C) at the center. The smallest amount of temperature decrease (2.4^{0}C) at the same position was found at the center of 6" food carriers. The 2" food carriers lost 7.7^{0}C at the center within the first hour. After 1 hour holding, constant cooling rates, such as 3^{0}C per hour for 2" food carriers, 2.6^{0}C per hour for 4" food carriers, and 2.3^{0}C per hour for 6" food carriers (see Table II and Figure 2), were found in each size of food carriers. As pictured in Figure 2, 6" food carriers could maintain food temperature above 140^{0}F (60^{0}C) for more than 5 hours. Both

TABLE I

COMPARISON OF THE TEMPERATURE DIFFERENCE IN 2, 4, 6 INCH FOOD CARRIERS AT 100 PERCENT FILL

Source	DF	Anova SS	Mean Square	F Value	P Value
Pansize	2	2946.74	1473.37	80.04	0.0001
Error	6	110.45	18.41		
Time	4	1822.97	455.74	719.89	0.0001
Time*Pansize	8	23.42	2.93	4.62	0.0610[b]
Error(Time)	24	15.19	0.63		
Position	2	537.39	268.69	73.17	0.0001[a]
Position*Pansize	4	29.58	7.39	2.01	0.2147[b]
Error(Position)	12	44.07	3.67		
Time*Position	8	3.97	0.50	0.71	0.4317[a]
Time*Position*Pansize	16	17.77	1.11	1.58	0.2810[b]
Error(Time*Position)	48	33.68	0.70		
Total	134				

(a) Following Winer (1962), the probablity values were adjusted for degrees of freedom, $F_{.95}$ (1, 6), to deal with the repeated measures.

(b) Following Winer (1962), the probablity values were adjusted for degrees of freedom, $F_{.95}$ (2, 6), to deal with the repeated measures.

TABLE II

MEAN TEMPERATURE DIFFERENCE AT THE CENTER, THE MIDPOINT, AND THE CORNER OF 2", 4", AND 6" FOOD CARRIERS DURING 1, 2, 3, 4, AND 5 HOURS INTERVALS

Pan Size	Percent Fill	Position of Probe	Temperature Decrease (^{0}C)/hour 1	2	3	4	5	Total
		Center	7.7	3.4	3.4	3.2	3.0	20.7
2"	100.0	Midpoint	5.0	3.3	3.2	3.1	3.2	17.8
		Corner	17.6	3.1	2.9	2.6	2.3	28.5
		Center	9.1	3.4	2.5	2.5	2.2	19.7
4"	100.0	Midpoint	7.8	3.3	2.4	2.6	2.1	18.2
		Corner	18.0	4.1	2.3	2.3	2.0	28.7
		Center	2.4	2.2	1.4	2.7	2.1	10.8
6"	100.0	Midpoint	3.4	2.9	1.6	2.5	2.1	12.5
		Corner	5.2	3.7	2.2	2.5	2.0	15.6
		Center	13.3	4.5	3.6	3.0	2.7	27.1
4"	50.0	Midpoint	13.4	4.4	3.2	3.2	2.4	26.6
		Corner	15.7	3.0	3.1	2.9	2.5	27.2
		Center	17.6	5.1	4.2	3.3	3.0	32.9
6"	33.3	Midpoint	18.2	4.4	3.3	3.2	2.5	31.6
		Corner	23.4	3.9	2.9	3.2	2.7	36.1
		Center	6.2	3.2	2.8	2.5	2.2	16.9
6"	66.7	Midpoint	6.2	3.3	2.7	2.7	1.9	16.8
		Corner	10.9	3.7	2.5	2.2	1.9	21.2

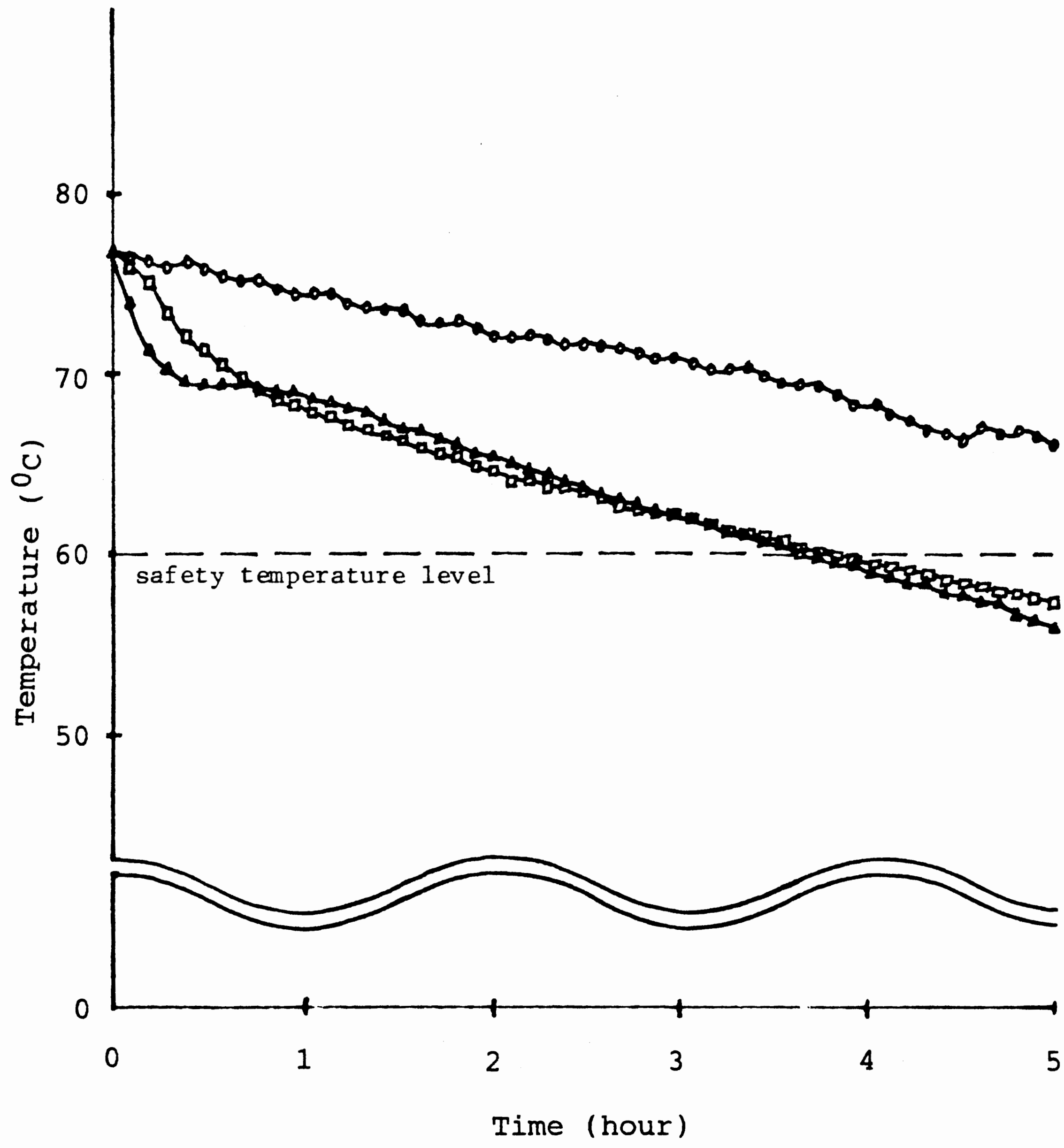

Figure 2. Comparison of Temperature Variances at the Center of 2"(Δ), 4"(□), and 6"(O) Food Carriers at 100 Percent Fill.

2" and 4" food carriers could maintain food temperature above 140^{0}F (60^{0}C) for about 3.5 hours.

The first null hypothesis stated that there were no significant difference in the heat retaining performance among 2", 4", and 6" food carriers at 100 percent fill. The results showed that mean temperature decrease was 7.7^{0}C within the first hour and 3^{0}C per hour after the first hour for the 2" food carriers, 9.1^{0}C within the first hour and 2.6^{0}C per hour after the first hour for 4" food carriers, and 2.4^{0}C within the first hour and 2.3^{0}C after the first hour for 6" food carriers (see Table II and Figure 2). Since the F values in Table I did indicate significant differences among 2", 4", and 6" food carriers at 1, 2, 3, 4, and 5 hours of holding and Table II and Figure 2 did exhibit the temperature differences in the sizes of food carriers within the first hour holding, the null hypothesis was rejected.

Table III and Table IV exhibited the comparison of between temperature variances in 4" and 6" food carriers with various percent capacity fills. Significant differences ($P < 0.05$) were found in: (1) percent capacity fill, (2) holding time, (3) temperature recording probe's position, and (4) the interaction between time and percent capacity fill. No significant difference was found in the interaction (1) between time and probe's position and (2) among time, percent fill, and probe's position. Table IV exhibited significant difference ($P < 0.05$) in the

TABLE III

COMPARISON OF TEMPERATURE DIFFERENCE IN 4 INCH FOOD CARRIERS AT 100.0 AND 50.0 PERCENT FILLS

Source	DF	Anova SS	Mean Square	F Value	P Value
PCFill	1	1530.17	1530.17	147.69	0.0003
Error	4	41.44	10.36		
Time	4	1505.74	376.43	3277.30	0.0001[a]
Time*PCFill	4	17.70	4.42	38.52	0.0034[a]
Error(Time)	16	1.84	0.11		
Position	2	276.46	138.23	39.46	0.0033[a]
Position*PCFill	2	17.20	8.60	2.46	0.1919[a]
Error(Position)	8	28.02	3.50		
Time*Position	8	4.23	0.53	3.00	0.1583[a]
Time*Position*PCFill	8	4.83	0.60	3.42	0.1381[a]
Error(Time*Position)	32	5.64	0.18		
Total	89				

(a) Following Winer (1962), the probablity values were adjusted for degrees of freedom, $F_{.95}(1, 4)$, to deal with the repeated measures.

TABLE IV

COMPARISON OF THE TEMPERATURE DIFFERENCE IN 6 INCH FOOD CARRIERS AT 100.0, 66.7 AND 33.3 PERCENT FILLS

Source	DF	Anova SS	Mean Square	F Value	P Value
PCFill	2	4876.41	2438.21	177.13	0.0001
Error	6	82.59	13.77		
Time	4	2056.24	514.06	701.72	0.0001[a]
Time*PCFill	8	66.61	8.33	11.37	0.0091[b]
Error (Time)	24	17.58	0.73		
Position	2	279.45	139.72	63.62	0.0002[a]
Position*PCFill	4	26.04	6.51	2.96	0.1275[b]
Error(Position)	12	26.36	2.20		
Time*Position	8	0.92	0.11	0.35	0.5757[a]
Time*Position*PCFill	16	14.10	0.88	2.69	0.1466[b]
Error(Time*Position)	48	15.74	0.33		
Total	134				

(a) Following Winer (1962), the probablity values were adjusted for degrees of freedom, $F_{.95}$ (1, 6), to deal with the repeated measures.

(b) Following Winer (1962), the probablity values were adjusted for degrees of freedom, $F_{.95}$ (2, 6), to deal with the repeated measures.

interaction of probe's position and percent fill in 6" food carriers.

Table V exhibited the comparison of temperature variances among 2", 4", and 6" food carriers holding 1 gallon of reconstituted mashed potatoes. The result indicated that significant differences ($P < 0.05$) were found in pan size, holding time, temperature recording probe's position, the interaction between time and probe's position, and the interaction between probe's position and pan size. Compared with Table V, Table VI exhibited significant differences ($P < 0.05$) in holding time and probe's position. There was no significant temperature difference found in the sizes of 4" and 6" food carriers holding 2 1/8 gallons of reconstituted mashed potatoes.

Figure 3 and Figure 4 pictured the temperature variances in 2", 4", and 6" food carriers at various percent capacity fills. Overall temperature variances within the first hour was found among 2", 4", and 6" food carriers. Compared with 2" and 4" food carriers holding 1 gallon of reconstituted mashed potatoes, 6" food carriers had the largest amount of temperature decrease (17.6^{0}C) (see Table II). In this situation, 6" food carriers maintained food temperature above 140^{0}F (60^{0}C) for 1 hour only (see Figure 3). When the volume of holding changed to 2 1/8 gallons, 6" food carriers had less temperature decrease (6.2^{0}C) than 4" food carriers (9.1^{0}C) (see Table

TABLE V

COMPARISON OF THE TEMPERATURE DIFFERENCE IN 2, 4, AND 6 INCH FOOD CARRIERS AT 100.0, 50.0, AND 33.3 PERCENT FILLS

Source	DF	Anova SS	Mean Square	F Value	P Value
Pansize	2	243.21	121.60	32.88	0.0006
Error	6	22.19	3.70		
Time	4	2736.66	684.17	932.74	0.0001[a]
Time*Pansize	8	17.18	2.15	2.93	0.1295[b]
Error(Time)	24	17.60	0.73		
Position	2	310.26	155.13	163.68	0.0001[a]
Position*Pansize	4	50.99	12.75	13.45	0.0061[b]
0002					
Error(Position)	12	11.37	0.95		
Time*Position	8	25.55	3.19	6.04	0.0493[a]
Time*Position*Pansize	16	6.41	0.40	0.76	0.5079[b]
Error(Time*Position)	48	25.40	0.53		
Total	134				

(a) Following Winer (1962), the probablity values were adjusted for degrees of freedom, $F_{.95}(1, 6)$, to deal with the repeated measures.

(b) Following Winer (1962), the probablity values were adjusted for degrees of freedom, $F_{.95}(2, 6)$, to deal with the repeated measures.

TABLE VI

COMPARISON OF THE TEMPERATURE VARIANCE IN 4 AND 6 INCH FOOD CARRIERS AT 100.0 AND 66.7 PERCENT FILLS

Source	DF	Anova SS	Mean Square	F Value	P Value
Pansize	1	0.77	0.77	0.07	0.8021
Error	4	42.68	10.67		
Time	4	1186.94	296.73	926.17	0.0001[a]
Time*Pansize	4	0.22	0.06	0.17	0.7013[a]
Error(Time)	16	5.13	0.32		
Position	2	370.90	185.45	43.23	0.0028[a]
Position*Pansize	2	4.95	2.48	0.58	0.4887[a]
Error(Position)	8	34.32	4.29		
Time*Position	8	1.68	0.21	0.77	0.4298[a]
Time*Position*Pansize	8	0.41	0.05	0.19	0.6854[a]
Error(Time*Position)	32	8.72	0.27		
Total	89				

(a) Following Winer (1962), the probablity values were adjusted for degrees of freedom, $F_{.95}$ (1, 4), to deal with the repeated measures.

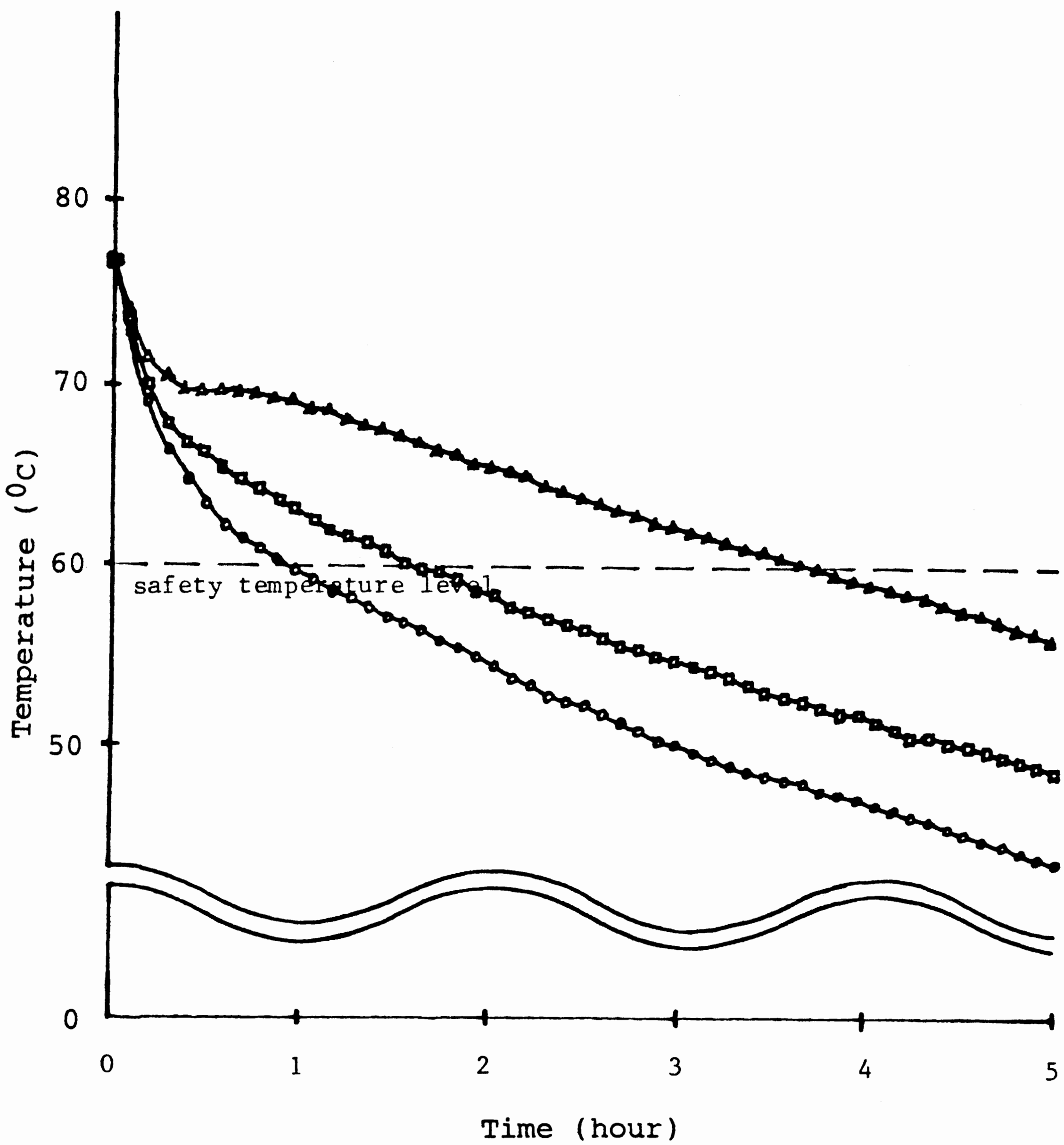

Figure 3. Comparison of Temperature Variances at the Center of 2" Food Carriers(Δ) at 100 Percent Fill, 4" Food Carriers(□) at 50 Percent Fill, and 6" Food Carriers (O) at 33.3 Percent Fill.

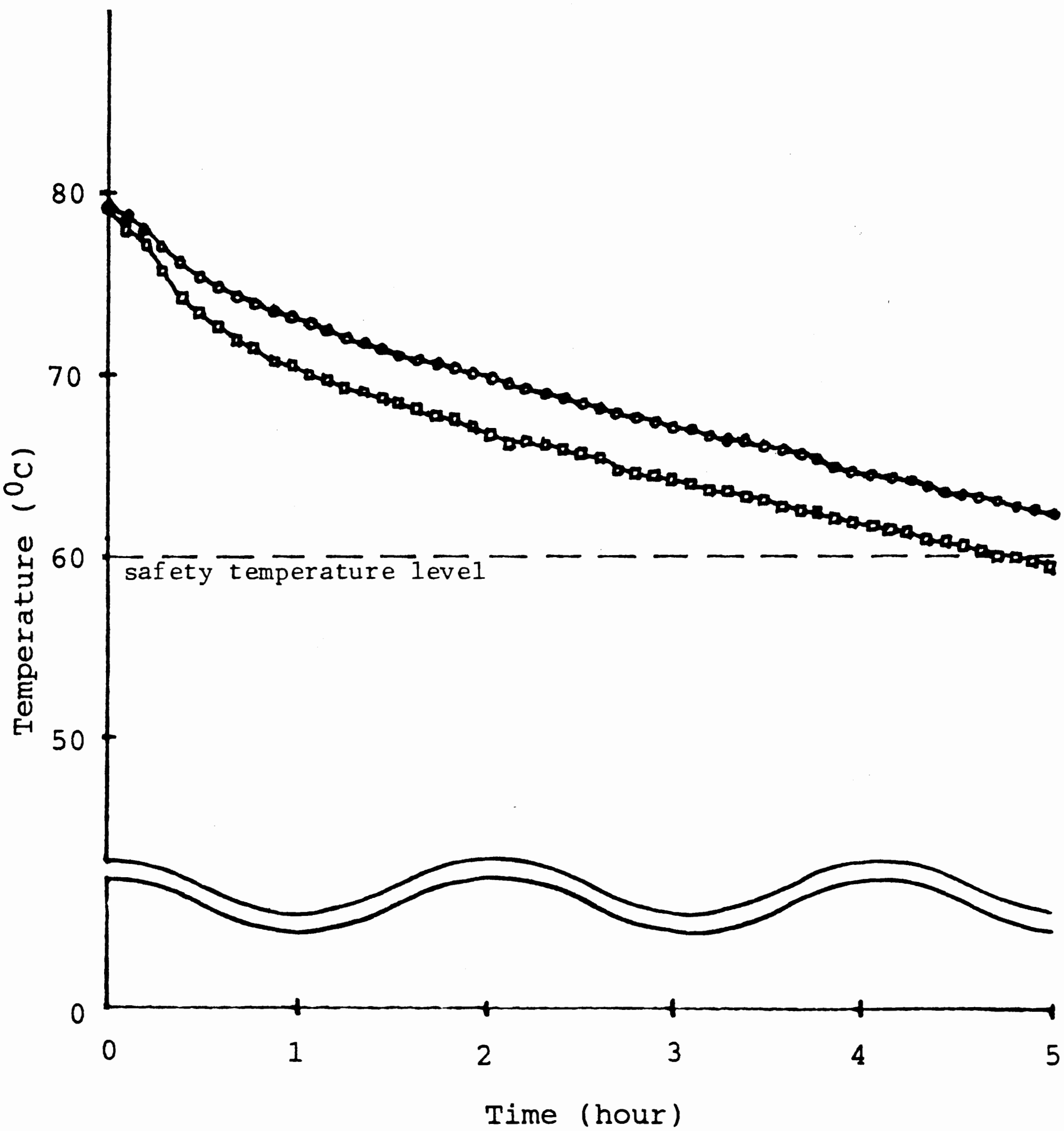

Figure 4. Comparison of Temperature Variances at the Center of 4" Food Carriers(□) at 100 Percent Fill and 6" Food Carriers(O) at 66.7 Percent Fill.

II). After 1 hour holding, the temperature variances were similar in different sizes of food carriers with a same volume of holding. In both 4" and 6" food carriers, the central temperature of 2 1/8 gallons of reconstituted mashed potatoes could be maintained above 140^0F (60^0C) for 5 hours (see Figure 4).

The second hypothesis stated that there were no significant difference in the heat retaining performance among 2", 4", and 6" food carriers when holding a constant volume of mashed potatoes. Temperature difference among 2", 4", and 6" food carriers were found within the first hour holding. Although F tests in Table VI indicated no significant difference ($P < 0.05$) in the size of 4" and 6" food carriers holding 2 1/8 gallons of reconstituted mashed potatoes for more than 1 hour, there were significant differences ($P < 0.05$) found in 2", 4", and 6" food carriers holding 1 gallon of reconstituted mashed potatoes for the same time periods. Since the F tests did indicate significant differences among the 2", 4", and 6" food carriers, the second null hypothesis was rejected.

Table II exhibited the temperature decreases at the center, the midpoint, and the corner of 2", 4", and 6" food carriers at different percent capacity fills and at 1, 2, 3, 4, and 5 hours of holding (also see Figures 5, 6, 7, 8, 9, and 10). The temperature decreases at the corner were most evident among the three positions. The largest amount of temperature decrease within the first hour was (23.4^0C)

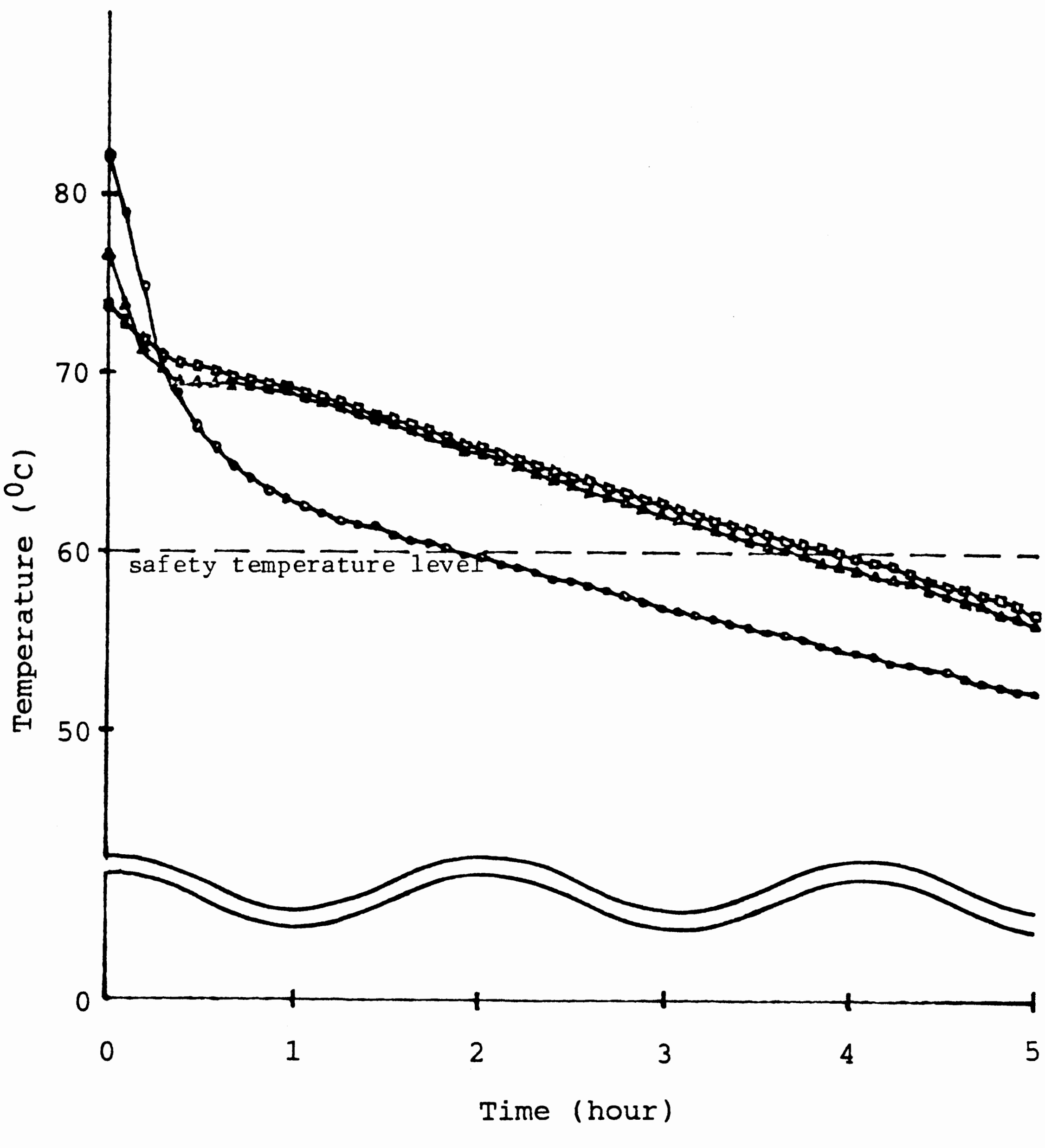

Figure 5. Comparison of Temperature Variances at the Center(Δ), the Midpoint(□), and the Corner(O) of 2" Food Carriers at 100 Percent Fill.

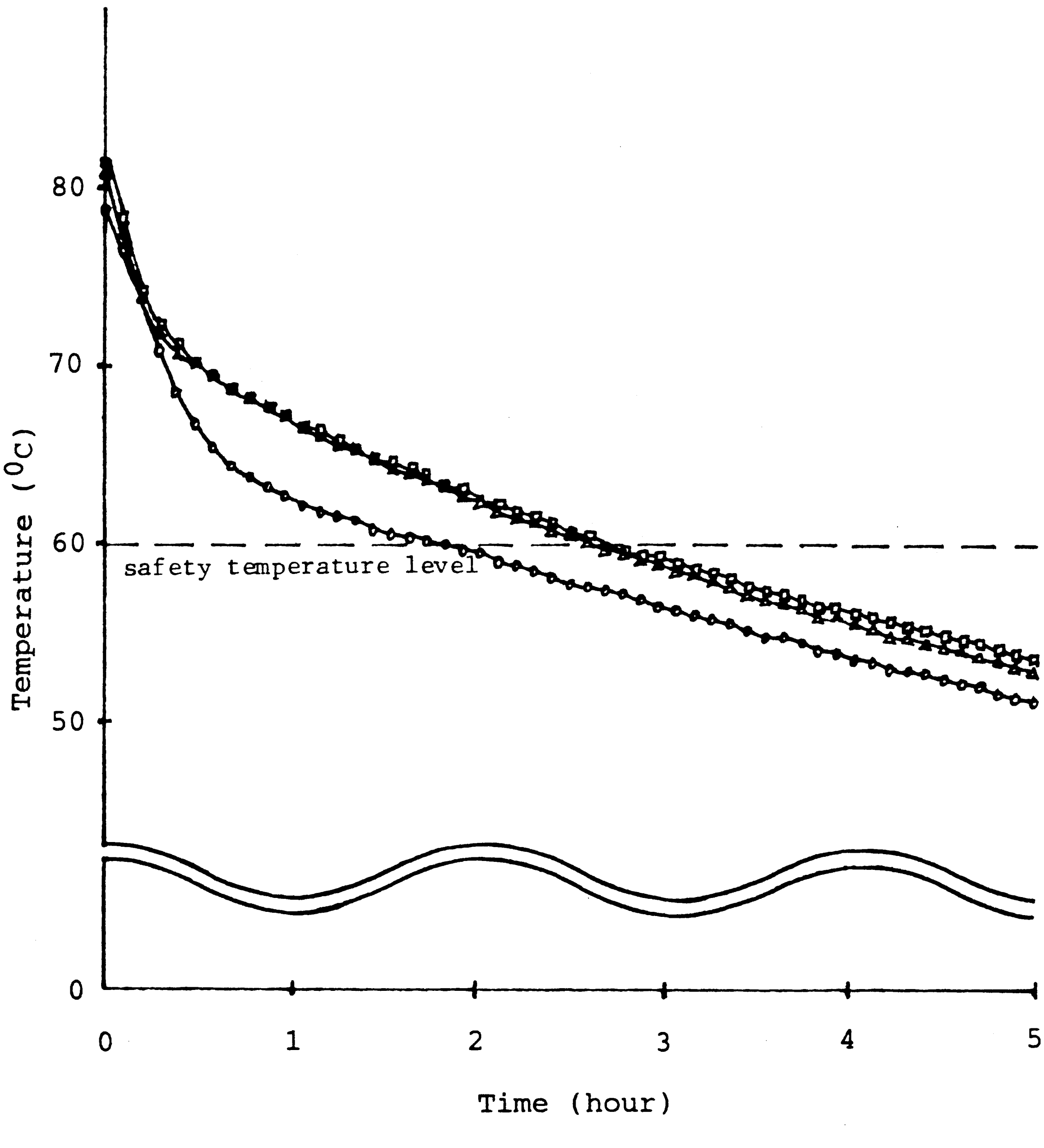

Figure 6. Comparison of Temperature Variances at the Center(Δ), the Midpoint(□), and the Corner (O) of 4" Food Carriers at 50 Percent Fill.

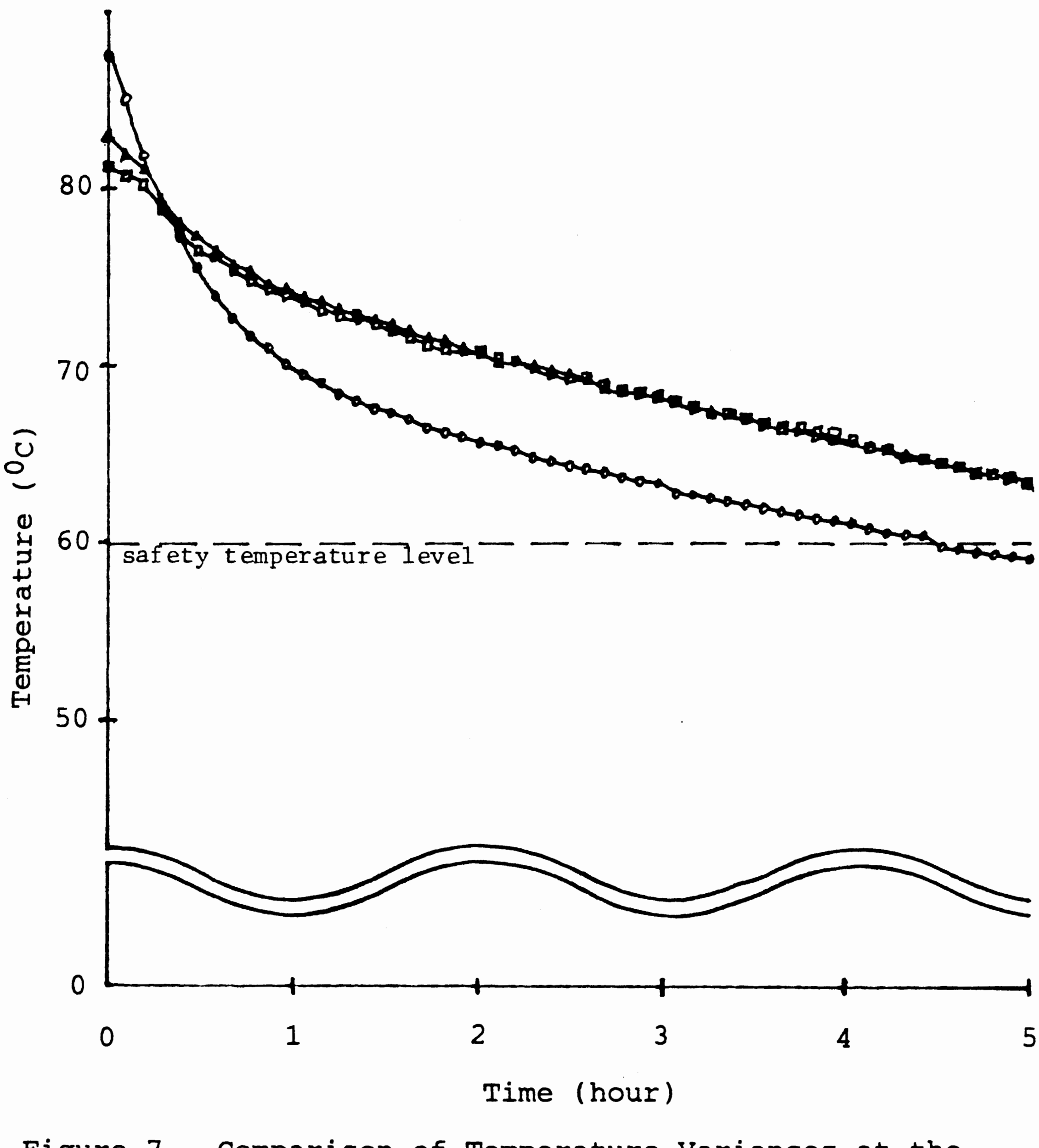

Figure 7. Comparison of Temperature Variances at the Center(Δ), the Midpoint(□), and the Corner (O) of 4" Food Carriers at 100 Percent Fill.

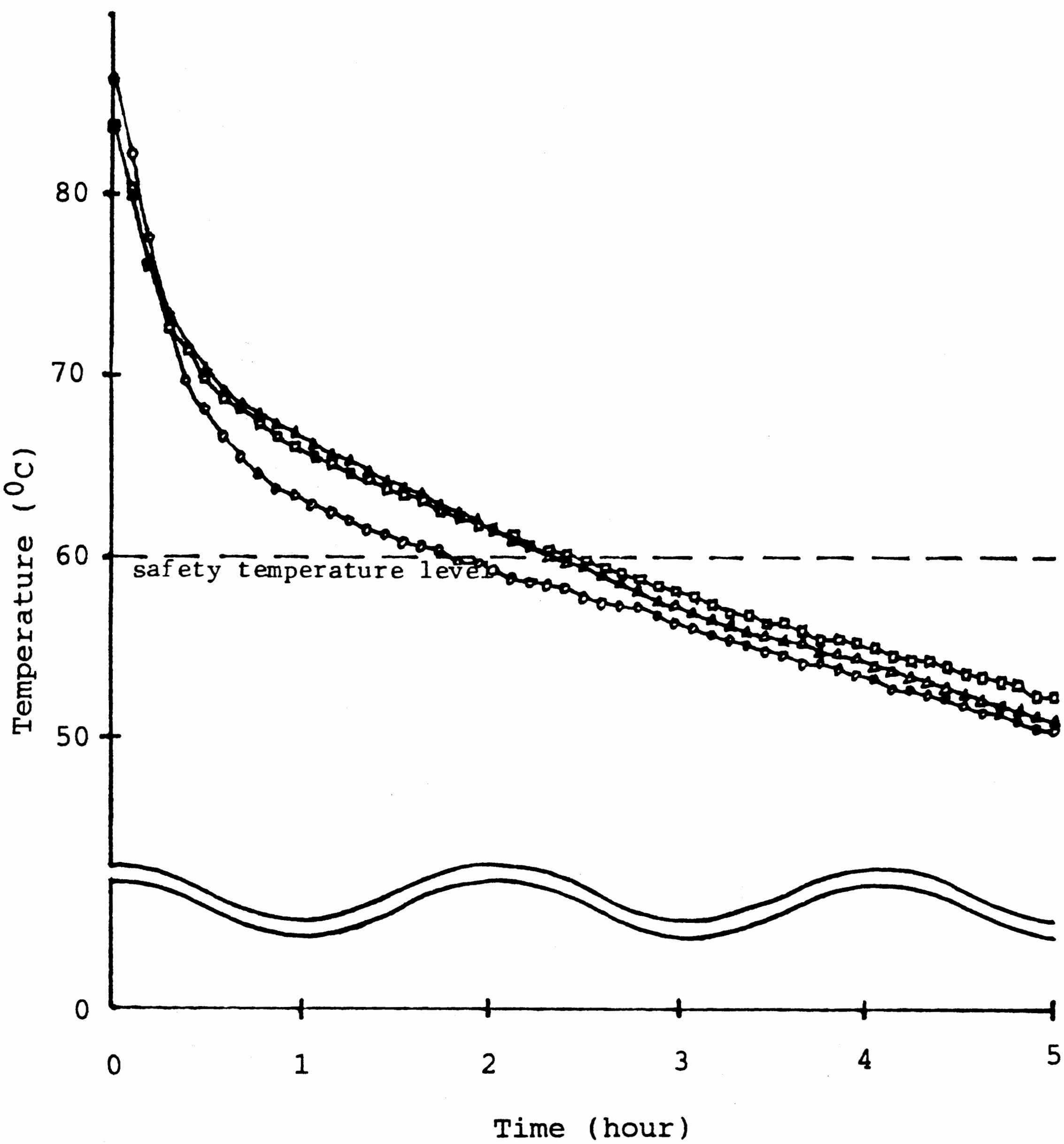

Figure 8. Comparison of Temperature Variances at the Center(Δ), the Midpoint(□), and the Corner (O) of 6" Food Carriers at 33.3 Percent Fill.

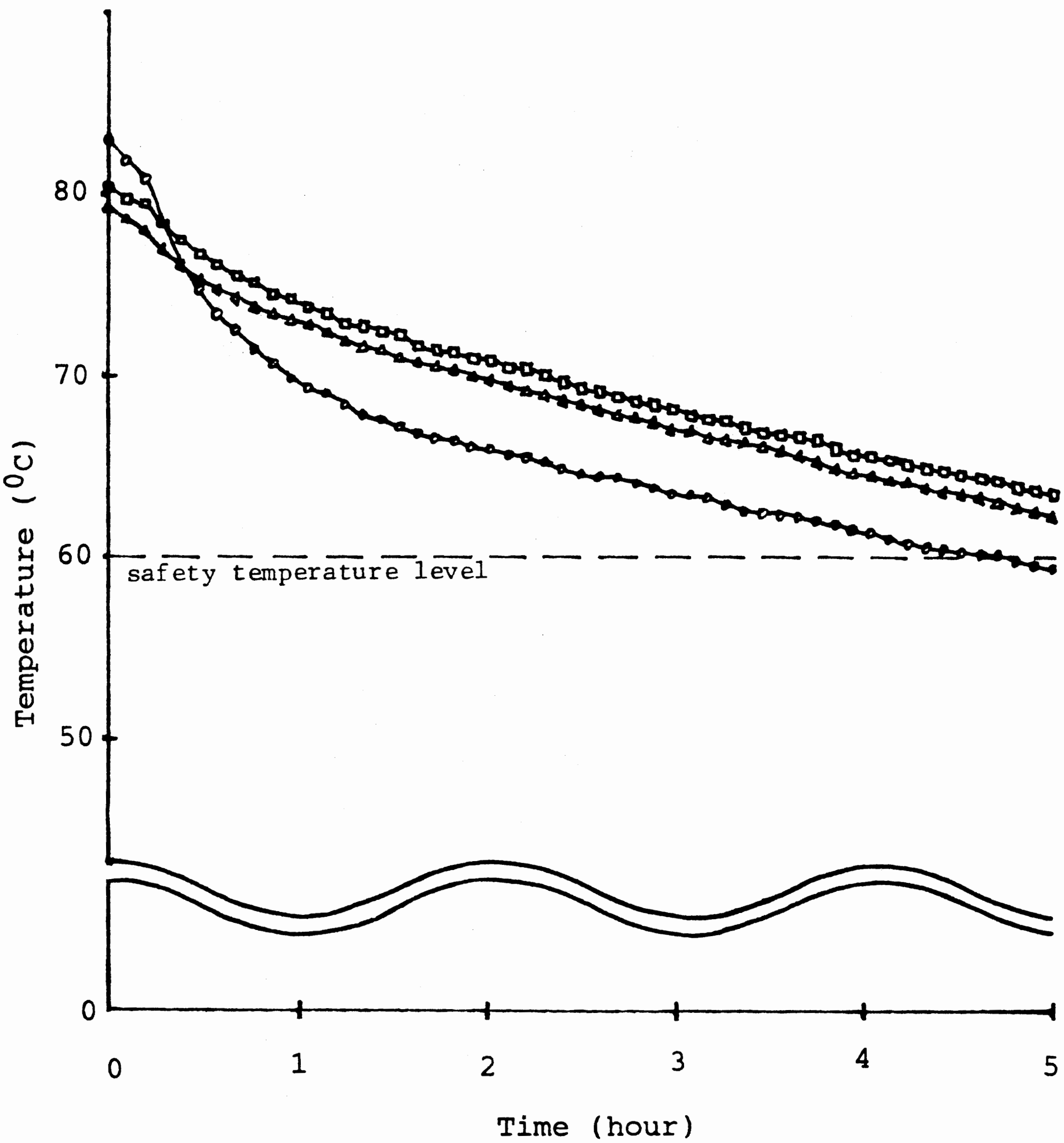

Figure 9. Comparison of Temperature Variances at the Center(Δ), the Midpoint(□), and the Corner (O) of 6" Food Carriers at 66.7 Percent Fill.

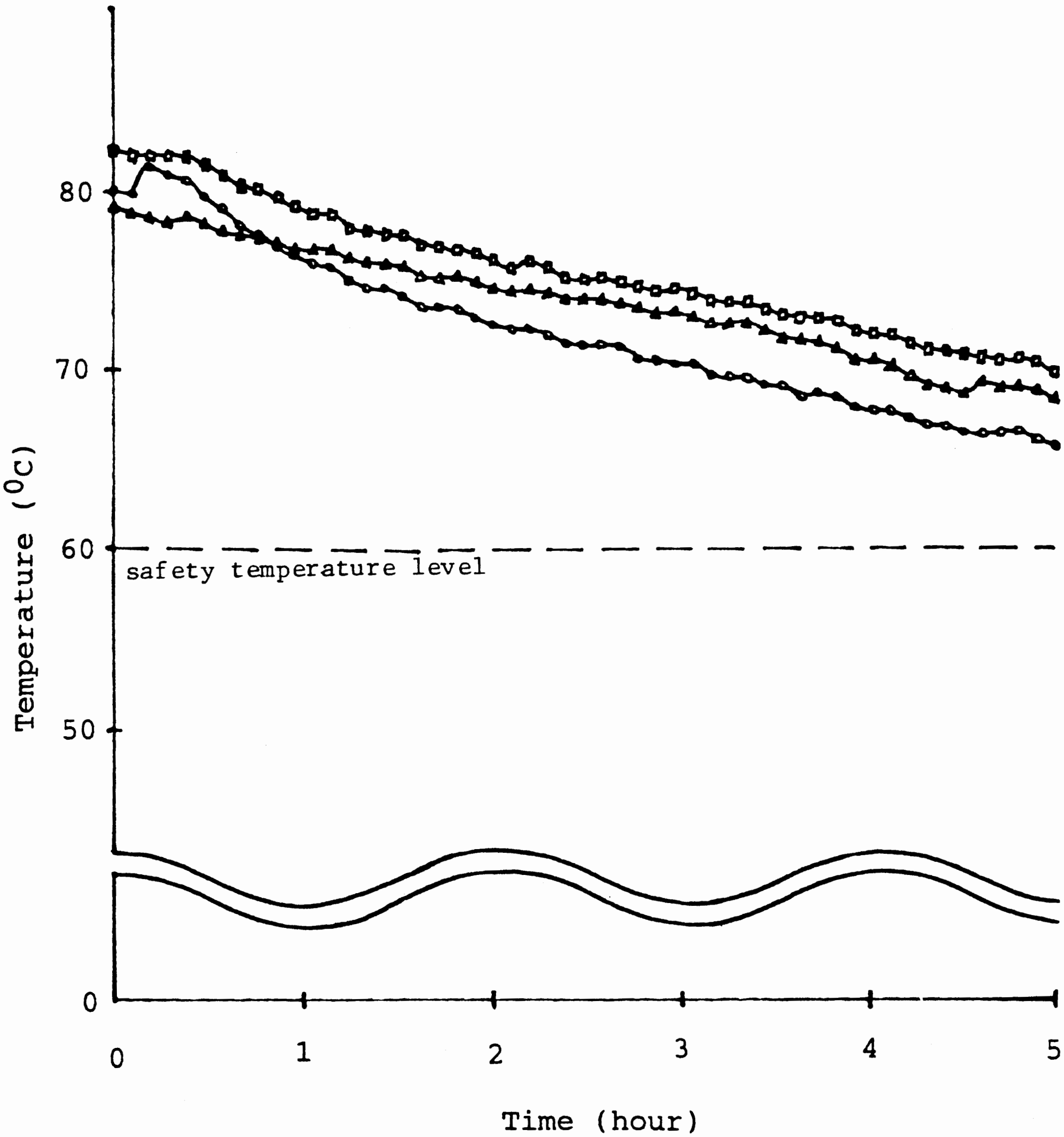

Figure 10. Comparison of Temperature Variances at the Center(Δ), the Midpoint(□), and the Corner (O) of 6" Food Carriers at 100 Percent Fill.

found in 6" food carriers at 33.3% fill. The smallest amount of temperature decrease within the first hour was (5.2^{0}C) found in 6" food carriers at 100% fill (see Table II). In 4" food carriers at 100% fill and in 6" food carriers at 66.7% fill and 100% fill, the temperature at the corner could be maintained above 140^{0}F (60^{0}C) for 5 hours (see Figures 7, 9, and 10). However, 2", 4", and 6" food carriers holding 1 gallon of reconstituted mashed potatoes could maintain food temperature above 140^{0}F (60^{0}C) for 2 hours only at the center of food carriers (see Figures 5, 6, 7, and 8).

In Tables V and VI, significant differences ($P < 0.05$) were found in in time and in probe's position. Significant differences in the interaction between probe's position and pan size was found in 2", 4", and 6" food carriers holding 1 gallon of reconstituted mashed potatoes (see Table V).

The third null hypothesis stated that there were no significant temperature differences among the center, the midpoint, and the corner of food carriers. Table II and Figures 5, 6, 7, 8, 9, and 10 did exhibit temperature difference among the positions of temperature recording probes within the first hour. In addition, F values exhibited in Tables V and VI did indicate significant differences ($P < 0.05$) among the positions of temperature recording probes in 2", 4", and 6" food carriers after 1, 2, 3, 4, and 5 hours of holding. So, the third null hypothesis was rejected.

Table VII exhibit the comparison of all percent capacity fills in 2", 4", and 6" food carriers. Results showed that there were significant differences ($P < 0.05$) found in the percent capacity fill, the interaction between time and percent capacity fill, the position of temperature recording probe, and the interaction between position and percent capacity fill.

Microbial Analysis

Table VIII exhibited the mean microbial counts from 1 gram of mashed potatoes at 0 hour immediately after preparation and at 1, 2, and 3 hours of holding. The initial microbial counts in reconstituted mashed potatoes was approximate 6×10^2 colony forming units (cfu)/ml (see Table VIII). The highest microbial count was found in 6" food carrier at 100% fill immediately after preparation, and the lowest microbial count was found in 6" food carrier holding 1 gallon of reconstituted mashed potatoes for 2

TABLE VIII

MEAN MICROBIAL COUNTS FROM 1 GRAM OF MASHED POTATOES

Pansize	Volume	0 hour	1 hour	2 hour	3 hour
2"	1 gallon	618	665	686	628
4"	1 gallon	306	346	295	366
6"	1 gallon	516	663	250	558
4"	2 1/8 gallons	731	923	850	548
6"	2 1/8 gallons	656	538	668	745
6"	3 3/16 gallons	1281	951	763	866

TABLE VII

COMPARISON OF TEMPERATURE DIFFERENCE AMONG 2", 4",AND 6" FOOD CARRIERS AT 100.0, 66.7, 50.0, AND 33.3 PERCENT FILLS

Source	DF	Anova SS	Mean Square	F Value	P Value
Treatment(TRT)	5	7318.49	1463.70	133.23	0.0001
Error	12	131.84	10.99		
Time	4	4323.69	1080.92	1849.46	0.0001[a]
Time*TRT	20	92.96	4.65	7.95	0.0016[b]
Error(Time)	48	28.05	0.58		
Position	2	764.76	382.38	156.90	0.0001[a]
Position*TRT	10	79.98	8.00	3.28	0.0426[b]
Error(Position)	24	58.49	2.44		
Time*Position	8	9.22	1.15	2.63	0.1308[a]
Time*Position*TRT	40	30.02	0.75	1.71	0.2068[b]
Error(Time*Position)	96	42.05	0.44		
Total	269				

(a) Following Winer (1962), the probablity values were adjusted for degrees of freedom, $F_{.95}(1, 12)$, to deal with the repeated measures.

(b) Following Winer (1962), the probablity values were adjusted for degrees of freedom, $F_{.95}(5, 12)$, to deal with the repeated measures.

hours. The comparisons of microbial count variance were exhibited in Table IX, X, XI for 2", 4", and 6" food carriers at various percent capacity fills of mashed potatoes.

As a result, significant difference ($P < 0.05$) in the sizes of food carriers was found only in 2", 4", and 6" food carriers holding 1 gallon of reconstituted mashed potatoes (see Table IX). Microbial counts found in 4" food carriers holding 1 gallon of reconstituted mashed potatoes were much lower than the counts found in 2" and in 6" food carriers with the same volume of holding for 0, 1, 2, and 3 hours. There was no significant difference ($P < 0.05$) exhibited in the holding hours in Tables IX, X, and XI.

TABLE IX

COMPARISON OF MEAN MICROBIAL COUNTS AMONG 2", 4", AND 6" FOOD CARRIERS AT 100.0, 50.0, AND 33.3 PERCENT FILLS

Source	DF	Anova SS	Mean Square	F Value	P Value
Pan Size	2	206252.67	103126.33	9.73	0.01
Holding hour	3	35429.58	11809.86	1.11	0.41
Error	6	63584.67	10597.44		
Corrected Tatal	11	305266.92			

A number of colonies from several plates were isolated and examined microscopically. The results showed that (1) no colony was found on anaerobic plates; (2) all colonies were gram positive rods; and (3) all produced spores. No further characterization was done.

TABLE X

COMPARISON OF MEAN MICROBIAL COUNTS AMONG 2", 4", AND 6" FOOD CARRIERS AT 100.0 PERCENT FILLS

Source	DF	Anova SS	Mean Square	F Value	P Value
Pan Size	2	204874.67	102437.33	3.73	0.09
Holding hour	3	69468.25	23156.08	0.84	0.52
Error	6	164808.00	27468.00		
Corrected Total	11	439150.92			

TABLE XI

COMPARISON OF MEAN MICROBIAL COUNTS AMONG 4" AND 6" FOOD CARRIERS AT 100.0 AND 66.7 PERCENT FILLS

Source	DF	Anova SS	Mean Square	F Value	P Value
Pan Size	1	24864.50	24864.50	0.85	0.43
Holding hour	3	14300.00	4766.67	0.16	0.92
Error	3	88209.50	29403.17		
Corrected Total	7	127374.00			

Discussion

The results of temperature variance studies indicated that food temperature in insulated bulk food carriers was influenced by the sizes of food carriers, the percent capacity fills of food carriers, and the time of holding. Food carriers at 100% fill demonstrated better heat retaining performance than the same size of food carriers at less percent fills. For example, 6" food carriers at 100% fill could effectively maintain food temperature above 140^{0}F (60^{0}C) for 5 hours, but 6" food carriers at 33.3% fill could maintain food temperature above 140^{0}F (60^{0}C) for 2 hours only.

In a small volume of holding, the heat retaining performance of 2" food carriers was more efficient than the performances of 4" and 6" food carriers. These could be explained from the space left in the 4" and 6" containers. There were more space left in 6" food carriers than the space left in 2" food carriers.

Although different temperature variance curves pictured in Figure 4, Table VI did exhibit no significant difference in the sizes of 4" and 6" food carriers holding 2 1/8 gallons of reconstituted mashed potatoes from 1 to 5 hours. This temperature variance could not be explained from the space left in the containers because 6" food carriers had more space left than 4" food carriers. The possible explanation was that the temperature retaining performance of 6" food carriers at 66.7% fill would be similar to the performance of 4" food carriers at 100% fill.

Heat loss at the corner of insulated bulk food carriers was much faster than the heat loss at either the center or the midpoint of food carriers within the first hour. After 1 hour holding, consistant cooling rates were found as follows: 3^{0}C/hour for 2" food carriers, 2.6^{0}C/hour for 4" food carriers, and 2.3^{0}C/hour for 6" food carriers. This result was similar to the cooling rate of 3^{0}C/hour found in Leong and Ebro's study (1988).

In microbial count studies, the initial microbial counts in reconstituted mashed potatoes was approximate 6×10^{2} cfu/ml. This could be explained by the spores found in the microbial plate counts because heat resistant spores could survive the reconstituted process.

Significant microbial count difference was indicated among the pan sizes of insulated bulk food carriers holding 1 gallon of reconatituted mashed potatoes. The microbial counts found in 4" food carriers were much less than the counts found in 2" food carriers with the same volume of holding. In addition, the microbial counts found in 6" food carriers holding 1 gallon of reconstituted mashed potatoes for 2 hours was the least one in all food carriers at various percent capacity fills. These results cound not be explained from air contamination in food carriers because 6" and 4" food carriers had more air left than 2" food carriers. A possible explanation could be that the microbial population present in the mashed potato powders used for the 6" food carrier was much less than the microbial populations present in the other mashed potato powders used for the other food carriers.

Several cans of mashed potato powders were used for this study. Different cans might have different shelf lifes and various microbial populations. Since heat-resistant spores could survive the reconstitution process, microbial counts present in reconstituted mashed potatoes might be influenced by the microbial population present in different mashed potato powders.

The 6" food carrier at 100% fill had unusually high initial microbial count. This might be explained by personal or environment contamination.

No significant microbial count increase was found in all insulated food carriers from 0 to 3 hours of holding. This result indicated that heat retaining performance of insulated bulk food carriers at various percent capacity fills could effectively control microorganism growth during hot-holding process for at least 3 hours.

CHAPTER V

CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

The performance of insulated bulk food carriers with respected to heat retention and microbial safety of mashed potatoes was investigated in this study. Three sizes of food carriers with various volumes of reconstituted mashed potatoes were used to compare temperature variance and microbial population growth. Temperature variances were tested at 1, 2, 3, 4, and 5 hours of holding, but microbial counts were analyzed at 0, 1, 2, and 3 hour intervals.

Conclusions

Under the conditions of the present study, the following conclusions were found: (1) 2", 4", and 6" insulated bulk food carriers at 100% fill could effectively maintain food temperature above 140^0F for 5 hours; (2) in a large volume of holding, the heat retaining performance of 6" food carriers were much better than the performance of either 2" or 4" food carriers; (3) in a small volume of holding, 2" food carriers had better heat retaining performance than the performance of either 4" or 6" food carriers; (4) heat loss was more evident at the corner of food carriers and within the first hour of holding in all food carriers with various percent capacity fills; (5) there was no significant microbial count increase found in reconstituted mashed potatoes held in the insulated bulk food carriers from 0 to 3 hours.

Implications

Food temperature, microbial safety, nutrient retention, and sensory quality are determining factors for the quality of food products served in foodservice institutions. Foodservice operators need more information related to the performance of food holding equipment for the efficient maintenance of food quality between production and pre-service periods. Foodservice operators also need to consider the following factors: (1) the amount of anticipated utilization, (2) the variability of food products, (3) the price and the heat retaining performance of insulated food carriers, (4) the transportation and mobility of insulated food carriers to service area, and (5) the amount of space allocated to the storage of the food carriers for the procurement of insulated food carriers.

Recommendations for Future Studies

Replications of this study using different types of food and different brands of insulated food carriers are needed. Further studies are also needed to examine the microbiological characteristics according to the holding time of food carriers at various percent capacity fills used in this study. More than two replications are needed for microbial studies. Additional studies are also needed to compare the performance among different types of food holding equipment such as convection oven, steam table, retheralization equipment, etc. Finally, additional studies are needed to examine the sensory quality of reconstituted mashed potatoes held hot for various time intervals in different types of food carriers.

BIBLOGRAPHY

Al-Obaidy, H., Klan, M. A., & Klein, B. P. (1983). Total plate counts and sensory evaluation of spaghetti/meat sauce entree held hot on a cafeteria counter. Presented at Institute of Food Technologists Annual Meeting. New Orleans, LA.

Anderson, S. J. (1978). Cooling Rates of Solid and Liquid Food Samples in Two Rethermalization Equipment Devices. M. S. thesis, Oklahoma State University, Stillwater.

Ang, C. Y. W., Chang, A. M., Frey, A. E., & Livingston, G. E. (1975). Effects of heating methods on vitamin retention in six fresh or frozen prepared food products. Journal of Food Science, 40, 997.

Anon. (1978). Foodservice market sales. Institutions, 82 (2), 37.

Asp, E. H. & Darling, M. E. (1988). Home-delivered meals: Food quality, nutrient content, and characteristics of recipients. Journal of The American Dietetic Association, 88 (1), 55-59.

Ayres, J. C., Mundt, J. O., & Sandine, W. E. (1980). Microbiology of Foods. San Francisco: W. H. Freeman and Company.

Baker, M. M. (1988). Meeting the challenge in foodservice management: Enhanced quality at less cost. Journal of The American Dietetic Association, 88 (4), 441-442.

Bartlett, M. (1989). Annual forecast 1989. Restaurants & Institutions, 99 (1), 32-35.

Behling, J. H. (1984). Guidelines for preparing the research proposal. MD: University Press of America.

Benftsson, N. & Dagersbog, H. (1978). Fried meat and patties -- the influence of preparartion and processing on quality and yield. In K. Paulus (Ed.), How Ready Are Ready-to serve Foods? (P. 147-155). New York: S. Karger.

Bidlack, W. R., Smith, C. H., Clemens, R. A., & Omaye, S. T. (1986). Nutrition and the elderly. Food Technology, 40 (9), 81-88.

Blaker, G. G., Newcomer, J. L., & Ramsey, E. (1961). Holding temperatures needed to serve hot food hot. Journal of American Dietetic Association. 38, 455-457.

Bogle, M. L. (1987). Dietitian's forum: Claiming and retaining the 'turf.' Food Management, 23 (10), 38.

Branion, H. D., Roberts, J. S., Cameron, C. R., & McCready, A. M. (1947). The loss of ascorbic acid in the preparation of old and freshly harvested potatoes. Journal of The American Dietetic Association, 23 (5), 414-420.

Brown, D. F. & Twedt, R. M. (1972). Assessment of the sanitary effectiveness of holding temperatures on beef cooked at low temperature. Application of Microbiology, 24, 599.

Brown, N. E. & Chyuan, J. A. (1987). Convective heat processing of turkey roll: Effects on sensory quality and energy usage. Journal of The American Dietetic Association, 87 (11), 1521-1525.

Bryan, F. L., Bartleson, C. A., & Christopherson, N. (1981). Hazard analyses, in reference to Bacillus cereus, of boiled and fried rice in Cantonese-style restaurants. Journal of Food Protection, 44, 500.

Chou, M. (1987). Does the "takeout food" trend pose new risks? Cereal Foods World, 32 (9), 625-626.

Connelly, M. N. (1987). Effective computer training. Food Management, 22 (5), 42-45.

Dahl, C. A. (1982). Hospital patient feeding systems: effect of meal assembly, meal distribution and meal service on sensory quality of food. Hospital Patient Feeding Systems. Washington, D.C.: National Academy Press.

Daum, K., Aimone, M., & Hollister, S. (1943). Ascorbic acid in institutional food. Journal of American Dietetic Association, 19, 693-694.

Gleim, E., Albury, M., McCartney, J. R., Visnyei, K., & Fenton, F. (1946). Ascorbic acid, thiamine, riboflavin and niacin content of potatoes in largescale food service. Food Research, 11 (6), 461-469.

Halliday, E. G. & Kahn, R. M. (1944). Aerobic acid content of white potatoes as affected by cooking and standing on the steam table. Journal of American Dietetic Association, 20 (4), 220-225.

Heller, C. A., Macay, C. M., & Lyon, C. B. (1943). Losses of vitamins in large-scale cookery. Journal of Nutrition, 26 (10), 377-380.

Hill, M. A., Baron, M., Kent, J. S., and Glew, G. (1977). The effect of hot storage after reheating on the flavor and ascorbic acid retention of precooked frozen vegetables. In G. Glew (Ed.), Catering Equipment and Systems Design. London: Applied Science Publishers.

Jonsson, L. & Karlstrom, B. (1976). The influence on hamburgers of degree of frying and of keeping hot. Analysis of protein quality (PER), Linoleic acid, and sensory quality (in Swedish). SIK-Rapport No. 397. Sweden: SIK - The Swedish Food Institute.

Jonsson, L. & Karlstrom, B. (1979). Warm-holding of herring. The influence of time, temperature, and moisture on fatty acids and sensory quality (in Swedish). SIK-Rapport No. 456. Sweden: SIK - The Swedish Food Institute.

Jonsson, L. & Karlstrom, B. (1980). Warm-holding of bread cod in different equipments. Influence on vitamin B6 and sensory quality (in Swedish) SIK-Rapport No. 477. Sweden: SIK - The Swedish Food Institute.

Jonsson, L. & Karlstrom, B. (1981). Effect of frying and warm-holding on protein quality, Linoleic acid content, and sensory quality of hamburgers. Lebensmittel-Wissenscharft, and Technologie, 14 (3), 127-130.

Jonsson, L. (1980). Nutritional changes in food handled in catering establishments. Summary of Dissertation (in Swedish). SIK-Rapport No. 482. Sweden: SIK - The Swedish Food Institute.

Jonsson, L. (1981). Studies on vitamin retention in steamed potato during warm-holding in air and in a nitrogen atmosphere. Lebensmittel-Wissenscharft, and Technologie, 14 (1), 43-46.

Jonsson, L. & Danielsson, K. (1981). Vitamin retention in food-service systems. Lebensmittel-Wissenscharft, and Technologie, 14 (2), 94-96.

Karlstrom, B. (1982). Quality changes during warm-holding of food in catering establishments. Summary of dissertation (in Swedish). SIK-Rapport No. 513. Sweden: SIK - The Swedish Food Institute.

Klein, B. P., Matthews, M. E., and Setser, C. S. (1984, June). Foodservice Systems: Time and Temperature Effects on Food Quality (North Central Regional Research Publication No. 293. Illinois: University of Illinois at Urbana-Champaign, Agricultural Experiment Station College of Agriculture.

Knight, J. B. & Kotschevar, L. H. (1978). Quantity Food Production, Planning, and Management. New York: Van Nostrand Reinhold Company.

Longree, K. (1980). Quality Food Sanitation (3rd ed.). New York: John Wiley and Sons.

Longree, K. & Blaker, G. G. (1982). Sanitary, Techniques in Foodservice. New York: Wiley.

Lundgren, B., Karlstrom, B., & Ljungquist, A. C. (1979). Effect of time and temperature of storage after cooking on the sensory quality of Bintjc potatoes. Journal of Science Food Agriculture, 30, 305-318.

Lydecker, T. (1988). Labor turnover: How to stop the revolving door. Restaurants & Institutions, 98 (1), 30-34.

Mastrian, L. K. (1985). The sensory evaluation program within a small processing operation. Food Technology, 39 (11), 127-129.

Maxcy, R. B. (1976). Fate of post-cooking microbial contaminants of some major menu items. Journal of Food Science, 41, 375.

Miller, J. L. (1988). Forecasting menu-item demand in foodservice operations. Journal of The American Dietetic Association, 88 (4), 443-449.

Nightingale, Mohd-Jan, A. (1983). Spaghetti firmness and ascorbic acid and thiamine retention in spaghetti and meat sauce held hot. M.S. thesis, Iowa State University, Ames.

Nelson, F. A. (1974). Abstract presented at the Annual Meeting of American Social Microbiologists.

Ockerman, H. W. & Dowiercial, R. (1982). Evaluation of 54 ^{0}C and 60^{0}C holding temperature on aerobic plate counts and coliform determinations of control and post cooking contaminated beef roast. Journal of Food Science, 47, 226.

Palacio, J. P., Spears, M. C., Vaden, A. G., & Dayton, A. D. (1985). The effect of organizational level and practice area on managerial work in hospital dietetic services. Journal of The American Dietetic Association, 85 (7), 799-806.

Paulus, K., Nowak, I. P., Zacharios, R. P., and Bognav, A. (1978). Influence of heating and keeping warm on the quality of meals. Annales de la Nutrition et de l' Alimentation, 32, 447-452.

Pratscher, M., Lydecker, T., & Bertagnoli, L. (1987). Tastes of America: How America loves to eat out. Restaurants & Institutions, 97 (12), 30.

Rose, L. N. (1971). Food temperature control. Hospitals, 45, 67-70.

Sawyer, C. A. (1987). Computer-assisted management: Role delineation for entry-level position in foodservice management. Journal of The American Dietetic Association, 87 (1), 75-77.

Shea, L. A. (1974). Heat-retaining capabilities of selected delivery systems. Journal of American Dietetic Association, 65, 430-436.

Smitherman, A. (1987). Responding to management challenges. Food Management, 22 (3), 48.

Spears, M. C. & Vaden, A. G. (1985). Foodservice Organizations. New York: John Wiley & Sons.

Steel, R. G. D. & Torrie, J. H. (1980). Principles and Procedures of Statistics (2nd ed.). New York: McGraw-Hill Book Company.

Streightoff, F., Munsell, H., Bendor, B., Orr, M. L., Relda, C., Leonard, M. H., Ezekiel, S. R., Kornblum, R., & Koch, F. G. (1946). Effect of large scale methods of preparation on vitamin content of foods. Journal of The American Dietetic Association, 22 (2) 117-125.

Synder, P. O., Matthews, M. E., & Marth, E. H. (1983). Fate of Bacillus cereus in whipped potatoes during pre-service holding as would occur in a conventional foodservice system. Journal of Food Protection, 46, 408-411.

Talburt, W. F. & Smith, O. (1987). Potato Processing (4th ed.). New York: Van Nostrand Reinhold Company.

Thompson, J. D. & Johnson, D. (1963). Food temperature preferences of surgical patients. Journal of American Dietetic Association, 43, 209-302.

Unklesbay, N., Maxcy, R. B., Knickrehm, M., Stevenson, K., Cremer, M., & Matthews, M. E. (1977). Foodservice Systems: Product Flow and Microbial Quality and Safety of Foods. North Central Regional Research Bull. No. 245. Missouri Agricultural Experiment Station, Columbia.

U.S.Department of Health, Education, and Wellfare (1978). "Food Service and Sanitation Manual-1976" Public Health Service. HEW Publication No. (FDA) 78-2081, Food and Drug Administration. Washington D.C.: Division of Retail Food Protection.

Weimer, J. P. (1985). The nutritional status of the elderly. National Food Review, 19 , 7.

Winer, B. J. (1962). Statistical Principles in Experimental Design. New York: McGraw-Hill Book.

Wolson, S. (1986). Taking inventory. Restaurants & Institutions, 96 (6), 127-130.

Wood, M. A., Collins, A. R., Stodola, V., Burgoin, A. M., & Fenton, F. (1946). Effect of large scale food preparation on vitamin retention in cabbage. Journal of American Dietetic Association, 22 (8), 677-682.

APPENDIX

INSTRUCTIONS FOR FRENCH'S IDAHO MASHED POTATOES

Instructions	175 Servings* (4¼ Gal)	87 Servings* (2⅛ Gal)	43 Servings* (1 Gal)	21 Servings* (2 Qt)
Water	12 qt	6 qt	3qt	1½ qt
Salt	3 tbsp	4 tsp	2 tsp	1 tsp
French's Idaho® Mashed Potatoes	5 lb 6 oz (full can)	2 lb 12 oz	1 lb 6 oz	11 oz

*One serving is #10 scoop (3.2 fl oz).

Optional: Butter or margarine may be added for richer, creamier texture. As with all machine-whipped potatocs, this may reduce yield approximately five servings.

For thicker mashed potatoes...add more potato mix. For thinner mashed potatoes...add more hot water.

Keep unused portions covered and stored in a cool, dry place.

Nutrition Information Per Serving

When prepared, each ½ cup portion contains 20 mg of Vitamin C.

This can makes 140 (½ cup) servings. Per ½ cup (4 oz) serving**

	Dry Potato Mix	Prepared Mashed Potatoes
Calories	60	60
Protein	2 g	2 g
Carbohydrate	14 g	14 g
Fat	0 g	0 g
Sodium	20 mg	170 mg
Potassium	290 mg	290 mg
Percentage of U.S. Recommended Daily Allowances. (U.S. RDA)		
Protein	2	2
Vitamin A	*	*
Vitamin C	30	30
Thiamin	2	2
Riboflavin	2	2
Niacin	4	4
Calcium	2	2
Iron	2	2

**When prepared as directed using no butter.

*Contains less than 2% of the U.S. RDA of this nutrient.

Ingredients: Potatoes, whey, sodium and calcium caseinates, vegetable monoglycerides, vitamin C, and calcium stearoyl lactylate. Sodium bisulfite, citric acid, and BHA (added to preserve quality). Nitrogen packed.

The R.T. French Company, Potato Division, Idaho Falls, Idaho USA 83401

VITA

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Candidate for the Degree of

Master of Science

Thesis: PERFORMANCE VARIABILITIES OF INSULATED BULK FOOD CARRIERS WITH RESPECT TO HEAT RETENTION AND MICROBIAL QUALITY OF MASHED POTATOES

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