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EFFECTIVENESS OF COLD-SERVING UNITS IN FOODSERVICE OPERATIONS AS DETERMINED BY TIME-TEMPERATURE PATTERNS AND BACTERIAL COUNTS

By

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A THESIS

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ABSTRACT

EFFECTIVENESS OF COLD-SERVING UNITS IN FOODSERVICE OPERATIONS AS DETERMINED BY TIME-TEMPERATURE PATTERNS AND BACTERIAL COUNTS

By

Angela Marie Fraser

Effectiveness of cold-serving units was determined by product temperatures ($\leq 7.2^{o}C$) and bacterial counts ($\leq 10^{5}$ CFU/g) of bulk (2.27 kg) and portioned (100 g) cottage cheese, tuna salad (100 g), and deviled eggs (90 $\pm$ 10 g) held in a laboratory for 24 h and three field sites for 4 h. In the laboratory, ice and mechanical cooling maintained cold temperatures; in field sites only mechanical cooling was used.

All products in the laboratory were $>7.2^{o}C$ after 2 h. In field sites, all portioned products were $<7.2^{o}C$ after 2 h. Differences were attributed to ice acting as an insulator and increasing product temperature. Bacterial growth in all products was less ≤ 1 log cycle in laboratory and field sites indicating potential for slow growth. A significant ($p < 0.05$) in mean product temperature but not bacterial counts was reported between bulk and portioned cottage cheese in laboratory ($t=-2.27$) and field sites ($t=-3.10$).

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Chapter I

INTRODUCTION

Sixty-three percent (63%) of reported bacterial foodborne disease events in foodservice operations have been attributed to "inadequate cold temperatures" of food (Bryan, 1978). Thus methods used to maintain cold temperatures of food in a foodservice operation need to be evaluated in relation to their effectiveness in preventing/minimizing microbiological growth.

Two widely accepted methods used to maintain cold temperatures of food in foodservice operations are refrigerated storage and cold-holding for self-service. Terms related to refrigerated storage and cold-holding for self-service are defined below. Where temperature guidelines were not available from United States (U.S.) sources (USDHEW, 1978), United Kingdom (U.K.) guidelines (DHSS, 1980) were incorporated.

Cold-holding for self-service (CHSS) is:

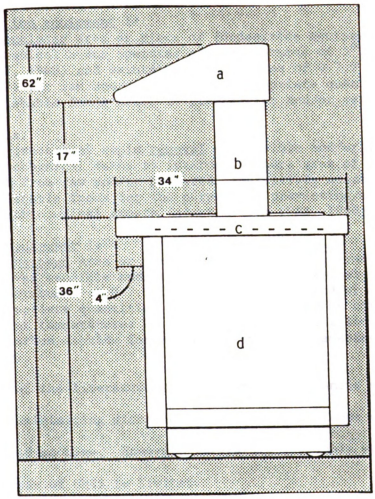
> the maintenance of target temperatures of 0-7.2°C (USDHEW, 1978) for convenient self-service of raw and/or prepared appropriate quantities of perishable food items on an open cold-serving unit for the purpose of preventing/minimizing microbiological growth.

Cold-serving unit is:

> foodservice equipment open on top that maintains by ice and/or mechanical means internal temperatures of 0-7.2°C of raw and/or prepared appropriate quantities of perishable food items displayed for convenient self-service. This equipment is also designed to improve the marketing potential of food items during cold-holding for self-service through display (Figure 1).

Figure 1. Diagram of a cold-serving unit.

a Sneeze guard
b Support for sneeze guard
c Mechanically cooled stainless steel basin
d Base of the cold-serving unit


62"
a
17"
b
34"
c
36"
4"
d

Refrigerated storage (or refrigeration) is:
the maintenance of internal temperatures of 0-7.2°C (USDHEW, 1978) of raw and/or prepared appropriate quantities of perishable foods prior to preparation and/or serving in enclosed refrigeration equipment for the purpose of preventing/minimizing microbiological growth (Figure 2).

Refrigeration equipment is:
an enclosed area or piece of foodservice equipment that by mechanical means operates at temperatures of 5°C ± 1.5°C (NSF, 1980) and maintains temperatures of 0-7.2°C (USDHEW, 1978) for raw and/or prepared, appropriate quantities of perishable foods prior to preparation and/or service.

Chilling is:
the process of rapid removal of sensible and/or latent heat by mechanical means to internal temperatures of 0-7.2°C in ≤2 h from raw and/or prepared, appropriate quantities of perishable foods for the purpose of preventing/minimizing microbiological growth (adapted from DHSS, 1980) (Figure 3).

Chilling equipment is:
an enclosed area or piece of foodservice equipment that removes sensible and/or latent heat to internal temperatures of 0-7.2°C in ≤2 h from raw and/or prepared, appropriate quantities of perishable foods by circulating air at temperatures of -3°C to -7°C or using liquid nitrogen or carbon dioxide for cryogenic chilling (adapted from DHSS, 1980).

Much of the literature reports the effectiveness of preventing/minimizing microbiological growth in foods during refrigerated storage. However, literature available on the effectiveness of CHSS is limited.

In the past, foodservice operators and scientists have assumed the operating principles of refrigerated storage applied to cold-holding for self-service. These principles, derived from U.S. sources, are as follows:

1) Refrigeration equipment must use mechanical cooling (USDHEW, 1978) to maintain optimum equipment and product temperatures.

2) Refrigeration equipment should operate at temperatures

Figure 2. Diagram of a refrigerated storage[a] system.

[a] [T]he maintenance of internal temperatures of 0-7.2°C (USDHEW, 1978) of raw and/or prepared appropriate quantities of perishable foods prior to serving in enclosed refrigeration equipment for the purpose of preventing/minimizing microbiological growth.

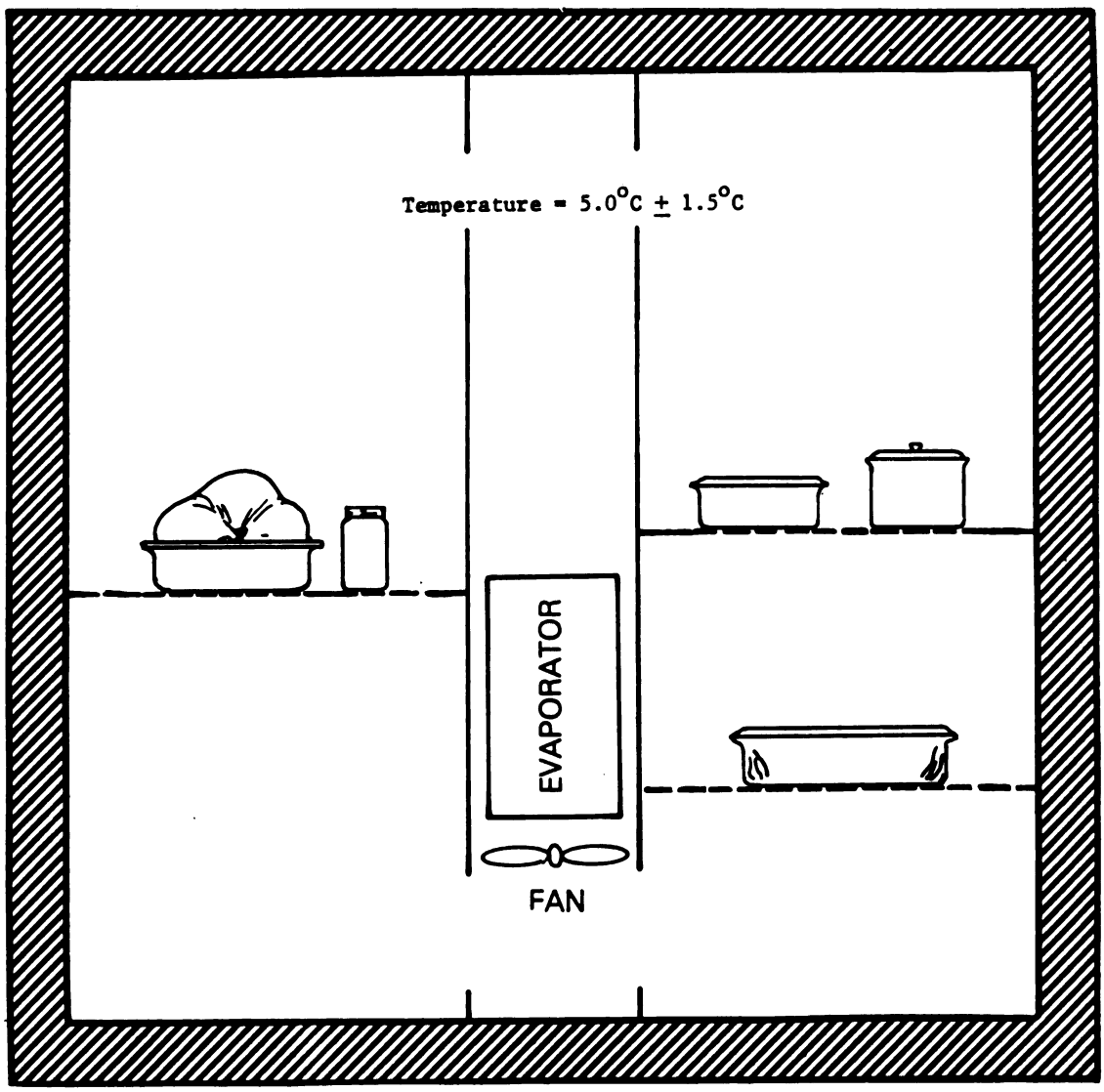
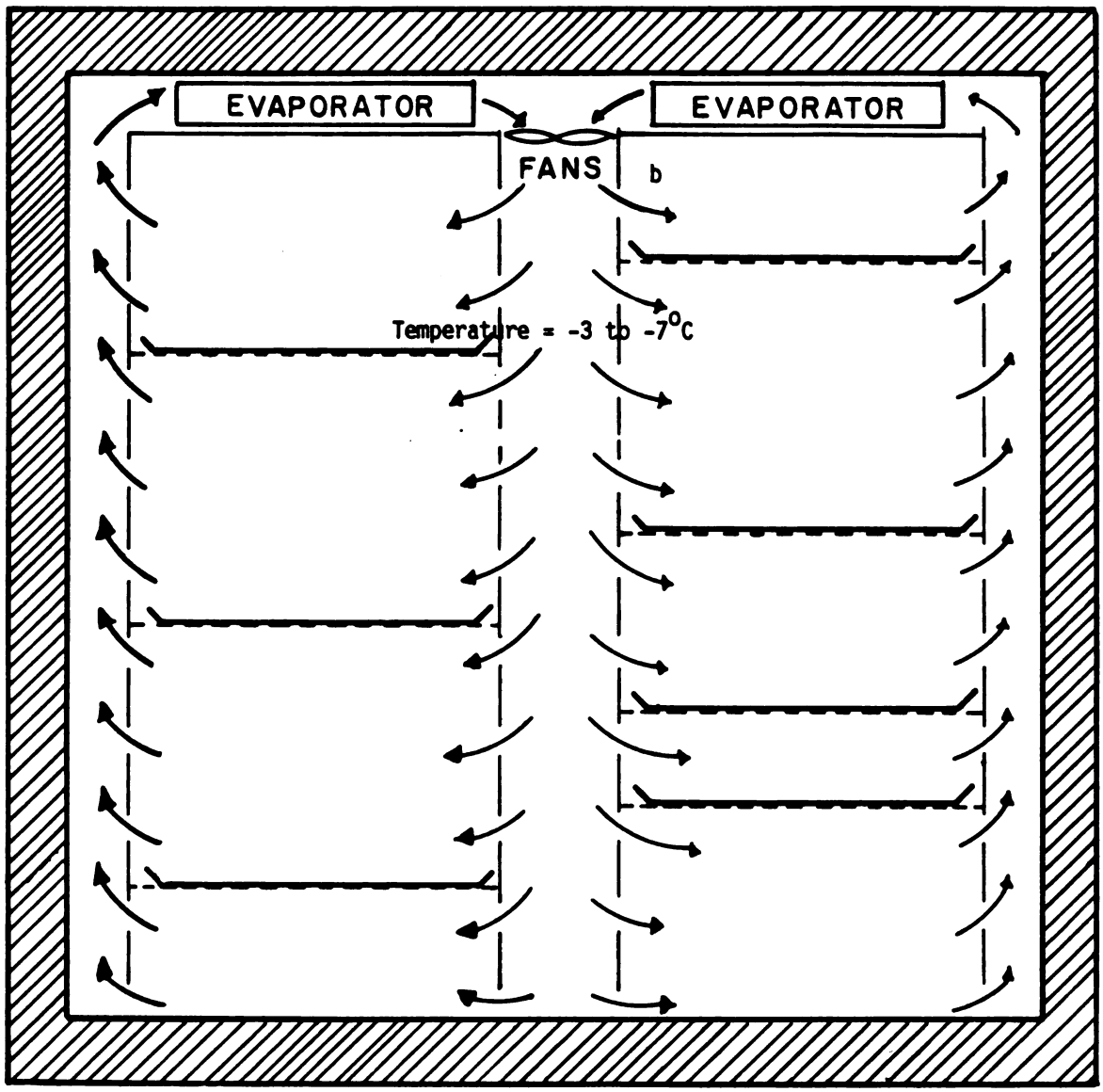

Temperature = 5.0°C ± 1.5°C
EVAPORATOR
FAN

Figure 3. Diagram of a chilling[a] system.

[a] [T]he process of rapid removal of sensible and/or latent heat by mechanical means to target temperatures of 0-7.2°C in ≤2 h from raw and/or prepared appropriate quantities of perishable foods for the purpose of preventing/minimizing microbiological growth (adapated from DHSS, 1980).

[b] Arrows indicate circulating air.


EVAPORATOR
EVAPORATOR
FANS
b
Temperature = -3 to -7°C

$\leq 5^{o}C \pm 1.5^{o}C$ (NSF, 1980).

3) Raw and/or prepared perishable foods held in refrigeration equipment should have internal temperaturs of $\leq 7.2^{o}C$ (USDHEW, 1978).

Operating principles for refrigeration have not been applied to CHSS. CHSS differs from refrigerated storage. Cold-serving units are open on the top for easy access to customers. Food on a cold-serving unit is exposed to room temperature and humidity. This would seem to have the potential to increase product temperature to $>7.2^{o}C$ especially when ambient temperatures are high as during summer months and/or in non-air conditioned rooms. Unlike refrigerators which much mechanical means of chilling, cold-serving units vary in type of cooling medium used to maintain cold temperatures. Some use only by mechanical cooling, some only ice, while others use a combination of mechanical cooling and ice. Guidelines have not been established for operating temperatures of cold-serving units. CHSS also requires internal temperatures of foods to be $\leq 7.2^{o}C$ (USDHEW, 1978).

The purpose of this study then was to observe the effectiveness of cold-serving units using the determinants of product temperatures $\leq 7.2^{o}C$ (USDHEW, 1978; NSF, 1980) and total mesophilic and psychrotrophic counts $\leq 10^{5}$ CFU/g (Hobbs and Gilbert, 1970; Fowler et al., 1973).

Chapter II

REVIEW OF LITERATURE

Potentially hazardous foods

Foods of major concern during CHSS in a foodservice operation have been labelled as potentially hazardous. The traditional definition of potentially hazardous is the one probably most accepted in the foodservice industry.

> Potentially hazardous foods are: [A]ny food that consists in whole or in part of milk or milk products, eggs, meat, poultry, fish, including synthetic ingredients, in a form capable of supporting rapid and progressive growth of infectious or toxigenic microorganisms. The term does not include clean, whole, uncracked, odor-free shell eggs or foods which have a pH level of 4.6 or below or a water activity (aW) value of 0.85 or less (USDHEW, 1978).

In 1986, the Food and Drug Administration re-evaluated the definition for potentially hazardous foods. Currently the term is defined as:

> Potentially hazardous foods are: [A]ny food or food ingredient, natural or synthetic, in a form capable of supporting (1) the rapid and progressive growth of infectious or toxigenic microorganisms or (2) the slower growth of *C. botulinum* (Food and Drug Administration, 1986).

Some of the foods not traditionally considered as a source of baterial pathogens, (e.g. raw vegetables), and reports of growth of bacteria on them are summarized below. Most of these foods are

frequently held on a cold-serving unit in foodservice operations. *Shigella* (Velaudapillas et al., 1969), *Pseudomonas aeruginosa* (Shooter et al., 1971; Kominos et al., 1972), enterotoxigenic *Escherichia coli* (Merson, 1976), and two species of *Aeromonas* (Callister and Agger, 1987) have been isolated from non-cooked vegetables. Another study reported that 80% of samples of raw vegetable salads had aerobic colony counts of $>10^6$ CFU/g and thus could support the growth of pathogens (Sadik et al., 1985). *Salmonella typhidium* and *Bacillus cereus*, more common foodborne pathogens, were shown to significantly grow in fresh unconcentrated lettuce juice (Maxcy, 1982). *Listeria monocytogenes*, a psychrotrophic pathogen, has also been isolated from cole slaw (Schlech et al., 1983) and cabbage juice (Conner et al., 1986).

Temperature control practices during CHSS

Research studies on time-temperature patterns of CHSS are limited. Klein (1984) reviewed foodservice-microbiological studies on the effects of time-temperature on food quality in foodservice systems. Of the 22 studies summarized, not one investigated the microbiological growth during CHSS. Only two studies investigating the effectiveness of CHSS on a cold-serving unit were found in the literature. Both studies were conducted by the United States Army Natick Development Center (Silverman et. al., 1975; O'Brien et al., 1984).

Modification to the Travis Air Force Base feeding system was evaluated using temperature measurements and bacterial plate counts (Silverman et al., 1975). The guideline for temperature compliance

was a preparation and serving temperature of ≤12.5°C (Fowler et. al., 1973), which is greater than temperature guidelines of 7.2°C recommended in A Model Food Service Sanitation Ordinance (USDHEW, 1978). Modifications included the introduction of new processing equipment, a specialty meal operation, a chilled and frozen food operation which included a remote reconstitution facility, centralized preparation of raw salads, a modular fast food facility and a limited training program for foodservice personnel. After modification of the feeding system, more than 75% of temperatures of the chilled items displayed on salad bars and serving lines were non-compliant (≤12.5°C) as against 60% prior to modification.

A study at Moncrief Army Hospital at Fort Jackson, SC tested the effectiveness of an Advanced Preparation Food Service System that employs a combination of cook/freeze, cook/chill, and cook/serve production methods along with rethermalization carts for patient tray delivery (O'Brien et al., 1984). Temperature compliance was also defined as preparation and serving temperature of ≤12.8°C (Fowler et al., 1973), which is greater than the temperature guideline of 7.2°C in A Model Food Service Sanitation Ordinance (USDHEW, 1978). Forty-two percent (42%) of samples of tuna, chicken, salmon, turkey and ham salads held chilled for service in refrigerated display cases and salad bars had temperatures that were non-compliant (≤12.5°C).

Pathogenic bacteria and possible growth at >7.2°C

Pathogenic bacteria that might be able to grow during CHSS are listed below. Selected literature was used to cite each pathogen's ability to grow at <7.2°C.

Fifty-five percent (55%) of reported bacterial foodborne disease events in the U.S. during 1982 were caused by *Staphylococcus aureus* and *Salmonella* (MacDonald and Griffin, 1986). *Clostridium botulinum* accounted for 14% of the outbreaks and is the most dangerous of the foodborne pathogens. Other less common foodborne pathogens such as *Aeromonas* sp., enterotoxigenic *Escherichia coli*, *Listeria monocytogenes*, *Pseudomonas aeruginosa* and *Yersinia enterocolitica* may join the ranks of these more notable foodborne pathogens and must not be overlooked when evaluating their growth at $\geq 7.2^{o}C$.

Almost all of the foodborne pathogens and many of the food spoilage organisms are mesophilic, growing optimally between 30-45^{o}C and only slowly from 5-15^{o}C (Banwart, 1981). Some foodborne pathogens, such as *Aeromonas*, *Listeria monocytogenes*, and *Yersinia enterocolitica* are psychrotrophic, growing best between 25-30^{o}C (Banwart, 1981). The organisms to be discussed are summarized alphabetically in Table 1 along with the foods associated with growth, minimum temperature of growth, and criteria for illness/outbreak. Each organism will be listed individually, including a review of growth at or near 7.2^{o}C.

Aeromonas. *Aeromonas* sp. has been reported to cause gastroenteritis in humans (Agger et al., 1985; Goodwin, 1983) and should be regarded as a psychrotrophic foodborne pathogen associated with grocery store produce (Callister and Agger, 1987) and retail samples of fish, seafood, poultry, red meat, and raw milk (Palumbo et al., 1985). *Aeromonas* sp. has an optimum growth temperature of 25-30^{o}C (Banwart, 1981) but has a growth range between 0-41^{o}C (von

Table 1. Summary of foodborne pathogens and their ability to grow at or near cold-holding for self-service temperatures (7.2°C).

Organism	Foods associated with reported growth	Lowest temperature of growth and toxin production	Criteria for illness/ outbreak
		- °C -	- CFU/g -
Aeromonas sp.	Animal origin, raw vegetables	4-5	NA
Bacillus cereus	Cream-filled baked goods, cream, lettuce, milk, potatoes, rice salads	10.0	$\geq 10^5$
Clostridium botulinum	Animal origin, canned foods, potatoes, smoked fish	3.3	
Enterobacteriaceae (*Klebsiella*, *Enterobacter*, *Serratia*)	Green vegetable salads		NA
Enterotoxigenic *Escherichia coli*	Animal origin, cheese, milk, mixed vegetable salads, raw fruits and vegetables	4.0	10^6-10^{10}
Listeria monocytogenes	Cole Slaw, cabbage, Mexican-style cheese, pasteurized milk	3.0	NA

Table 1 (continued). Summary of foodborne pathogens and their ability to grow at or near cold-holding for self-service temperatures (7.2°C).

Organism	Foods associated with reported growth	Lowest temperature of growth and toxin production	Criteria for illness/ outbreak
		- °C -	- CFU/g[a] -
Pseudomonas aeruginosa[b]	Lettuce/lettuce juice, raw vegetables	8.0	
Salmonella	Animal origin, eggs, dairy	5.2	10^5-10^{10}
Staphylococcus aureus	Animal origin, eggs, tuna, chicken, potato, and macaroni salads, cream pastries and pies, eclairs, sandwich fillings, milk and dairy	5.0	$\geq 10^5$
Yersinia enterocolita	Animal origin, raw milk, tofu	4.0	10^9

[a] CFU/g = colony forming units per gram.

[b] Pseudomonas aeruginosa is not pathogenic to normally health humans but can cause foodborne gastroenteritis in hospitalized patients.

Graevenitz, 1985). Laboratory criteria is not yet available for determining an outbreak of *Aeromonas* sp.

Palumbo et al. (1985) detected counts of *Aeromons hydrophila* from 1×10^2 to 5×10^5 CFU/g in virtually all retail red meats, chicken, raw milk, and seafood sampled. The counts generally increased 10- to 1,000- fold after refrigerated storage (5^oC) for seven days indicating *A. hydrophilic* is capable of competitive psychrotrophic growth in foods of animal origin.

Aeromonas hydrophila and *A. caviae* were isolated from retail grocery store produce which included parsley, spinach, celery, alfalfa sprouts, broccoli, and lettuce (Callister and Agger, 1987). Both *Aeromonas* strains showed growth in one day at 35 and 22^oC. At 12^oC, growth slowed, but all strains grew within 48 h. Growth at 5^oC was considerably slower but *A. hydrophila* did grow in 9 to 11 days, and *A. caviae* grew in 10 to 13 days.

Bacillus cereus. Implicated foods in reported outbreaks of *Bacillus cereus* foodborne gastroenteritis in the U.S. usually include cereals, cream-filled baked goods, custard, rice, pinto beans, potatoes, soups, stews and gumbos (Bryan, 1985). *Bacillus cereus* has an optimum growth temperature of $28\text{-}45^oC$ (Gordon, 1974) but is still able to grow slowly at 10^oC. Laboratory criteria for determining an outbreak of *Bacillus cereus* is $\geq 10^5$ CFU/g from incriminated foods (Bryan, 1985).

Multiplication of *Bacillus cereus* occured in pasteurized milk between $4.5\text{-}7.2.5^oC$ (Cox, 1975). Pasteurized cream held at 10^oC was unacceptable after 2 days, due to counts of *Bacillus cereus* $>10^6$.

Thus *Bacillus cereus* was presumed to be able to multiply to significant numbers in pasteurized dairy products, thus suggesting a limitation of refrigeration temperatures in preventing/minimizing growth of the organism.

Lettuce juice was also reported as a potential vehicle of transmission for foodborne pathogens (Maxcy et al., 1982). *Bacillus cereus* was inoculated into fresh lettuce juice and incubated at 10 and 20°C. *Bacillus cereus* needed an incubation temperature of 20°C for significant growth in fresh unconcentrated lettuce juice.

Clostridium botulinum type E. *Clostridium botulinum* type E produces a neurotoxin which when consumed frequently results in death. Implicated foods include canned foods, potatoes, smoked meat, poultry, and fish products (Bryan, 1985). *C. botulinum* has been reported to grow at temperatures as low as 3.3°C (Schmidt et al., 1961), but has an optimum growth temperature of 30-40°C (Banwart, 1981). Food containing botulinal toxin in any amount is unacceptable.

Schmidt et al. (1961) observed growth and toxin production by two strains of *C. botulinum* type E at 3.3°C in beef stew medium. Vacuum packed smoked ciscoes inoculated with type E spores and held at 10°C showed toxin production in five days (Kautter, 1964). Toxin production was also observed in fresh herring inoculated with 10^2 spores/g *C. botulinum* type E after 15 days storage at 5°C (Cann et al., 1965).

Enterobacteriaceae. Enterobacters can show visible growth at 7°C after 4-7.2 hours and at 10°C after 2.5-4.5 h. Wright et al. (1976)

reported a high frequency of recovery and high counts of the *Klebsiella-Enterobacter-Serratia* group from fresh vegetable salads obtained from a hospital kitchen prior to delivery to wards and before addition of spices and dressings. The authors concluded that these bacteria are not necessarily contaminants from humans, however, the vegetables may serve as a reservoir to *Klebsiella-Enterobacter-Serratia* for the colonization and infection of susceptible patients.

Kklebsiella was isolated from 21 of 47 washed samples of green vegetable salad (Casewell and Phillips, 1978). The immediate source of the organism was not believed to be the natural flora of the vegetables but rather the hospital kitchen, where equipment, utensils, and working surfaces were contaminated with klebsiella.

Enterotoxigenic *Escherichia coli*. *Escherichia coli*, an enteric bacteria is of concern for its possible contribution to foodborne gastroenteritis. Implicated foods involved in enterotoxigenic *E. coli* outbreaks include cheese, raw fruits and vegetables, salads of mixed vegetables, meat, poultry, and fish (Bryan, 1985). Although *Escherichia coli* has a optimum growth temperature of 37°C, it can grow as low as 5-10°C (Banwart, 1981). Laboratory criteria for determining an outbreak of *E. coli* are counts of 10^6-10^{10} CFU/g from incriminated foods (DuPont et al., 1971).

Cooling rates and *E. coli* growth in white sauce and beef broth in 2½, 4 and 8 gal. batches at 5.5°C and 2, 4, and 8 gal batches at 8°C in enclosed refrigeration equipment was investigated (Longree and White, 1955). Counts of *E. coli* in white sauce and beef broth increased to $>10^4$ CFU/g at 8°C for all batch sizes. Only the 2.5 gal.

batch held at 5.5°C showed counts of *E. coli* equal to 10^4 CFU/g, thus indicating refrigerated storage temperatures should be ≤5.5°C.

Listeria monocytogenes. Food has recently been identified as a potential vehicle for *Listeria monocytogenes* foodborne disease (Listeria Conference, 1986). Implicated foods have been largely of animal origin, i.e. pasteurized milk (Fleming et al., 1985) and Mexican style cheese (Anonymous, 1986). However, leafy vegetables such as cabbage (Schlech et al., 1982) contaminated on the farm or during prolonged cold storage without subsequent cooking may represent a vehicle for transmission of listeriosis.

Listeria monocytogenes has an optimum growth temperature of 30-37°C (Listeria Conference, 1986). However, it is unique from most pathogens because of its ability to grow and survive at temperatures as low as 3°C (Listeria Conference, 1986) and to possibly increase in virulence at low tempertures (Farber, 1986). *Listeria monocytogenes* does not yet have laboratory criteria for determining a foodborne outbreak.

The presence of *L. monocytogenes* during the manufacture and subsequent storage at 3°C of cottage cheese was investigated in the event that the cheese was made from skim milk containing the pathogen (Ryser et al., 1985). *L. monocytogenes* survived both the manufacturing and storage. *L. monocytogenes* has also been reported to survive during the manufacture and storage of other cheese varieties (Stajner et al., 1979; Anonymous, 1986).

In Canada coleslaw was implicated as the vehicle of transmission of *L. monocytogenes* which caused a major outbreak of infection

involving 41 persons (Schlech et al., 1982). It was presumed that the harvested cabbage was contaminated from soil fertilized with manure from sheep infected with listeriosis and that *L. monocytogenes* may have grown on the cabbage. Prolonged storage at 4°C of the raw cabbage prior to processing allowed a small initial inoculum of *L. monocytogenes* to proliferate to hazardous levels.

The influence of temperature, NaCl, and pH on the growth of two strains of *L. monocytogenes* in cabbage juice was also studied (Conner et al., 1986). The pathogenic strain of *L. monocytogenes* was less sensitive to NaCl but more sensitive to refrigeration (5°C) which indicates *L. monocytogenes* may be able to persist and proliferate on vegetables and in brines used in the process of fermenting vegetables.

Rosenow and Marth (1987) investigated the growth of *Listeria monocytogenes* in skim, whole and chocolate milk, and in whipping cream during incubation at 4, 8, 13, 21, and 35°C. Doubling times increased as temperature decreased: 4 h 27 min-6 h 55 min (13°C), 8 h 40 min-14 h 33 min (8°C), and 29 h 44 min-45 h 33 min (4°C) and showed maximum populatins reaching at least 10^7 cells/ml which should be of concern especially during refrigerated storage.

Pseudomonas aeruginosa. *Pseudomonas aeruginosa* has been suggested as being a possible source of foodborne gastroenteritis (Bryan, 1985). In a normally health adult 10^6 CFU/g or ml *P. aeruginosa* is needed for establishment in the bowel (Buck et al., 1969). *Pseudomonas aeruginosa* generally does not infect the healthy human but can colonize in the intestines of hospitalized patients.

Pseudomonas aeruginosa was isolated from samples of salads, cold and hot meats, and other foods prepared in eight hospitals, eleven canteens, and two schools (Shooter et al., 1971). Of the foods evaluated only salads had a high frequency of contamination by *P. aeruginosa* (often >1000 CFU/g). It was suspected that *P. aeruginosa* was introduced into the kitchen with incoming food such as meat and poultry.

Kominos et al. (1972) isolated *Pseudomonas aeruginosa* from tomatoes, radishes, celery, carrots, endive, cabbage, cucumbers, onions, and lettuce obtained from the kitchen of a general hospital with tomatoes yielding both highest frequencies of isolation and highest counts.

Salmonella. *Salmonella* was the most frequently isolated bacterial pathogen related to reports of foodborne disease in the U.S. in 1982 (MacDonald and Griffin, 1986). Poultry, meat, eggs and dairy products are the most important vehicles of transmission. *Salmonella* sp. grows optimally between 35-37^{o}C, but has been shown to grow at much lower temperatures. The laboratory criteria for determining a foodborne outbreak from *Salmonella* sp. is between 10^{5}-10^{10} CFU/g from incriminated foods (McCullough and Eisele, 1951a,b,c,d).

Custard, chicken a la king and ham salad were inoculated with *Salmonella senftenberg 755W, S. enteriditis, and S. manhattan* and incubated at 2^{o}C intervals from 4.4-10^{o}C (Angelotti et al., 1961). In custard the salmonellae underwent a gradual decrease in numbers at all temperatures from 4.4-10^{o}C. In chicken a la king, growth occured at tempertures of 6.7^{o}C and above. In ham salad no growth occured from

4.4-10oC. Salmonellae is presumably prevented in perishable foods when the internal temperature is $\leq 5.6^{o}C$.

One study reported minimum temperatures, as determined by visible growth for seven serotypes of salmonellae, from 5.5 to $6.8^{o}C$ (Matches and Liston (1968). At $7.5^{o}C$ the minimumum growth for *S. heidelberg*, *S. typhimurium*, and *S. derby* was after five days to incubation time. At $5.9^{o}C$ the three strains showed minimum growth after 12 days incubation. Thus, growth of *Salmonella* may occur at temperatures $\leq 6^{o}C$ after a relatively long period of time.

Mean generation times of nine serotypes of *Salmonella* inoculated on beef were also recorded (Mackey et al., 1980). The recorded temperatures for minimal growth were 8.1 h at $10^{o}C$; 5.2 h at $12.5^{o}C$; and 2.9 h at $15^{o}C$. No growth was reported at $7-8^{o}C$. These authors concluded that standards of $\leq 7.2^{o}C$ were too stringent for the temporary handling of meats and should possibly be increased to $10^{o}C$.

Catsaras (1981) studied the growth of *Salmonella* in minced meats at 6 and $10^{o}C$. Known numbers of *Salmonella typhimirium* cells were inoculated into minced meat samples with high and low initial levels of contamination by mesophilic aerobic bacteria. A strain of *S. typhimirium* was shown to grow well in minced beef at both 6 and $10^{o}C$. The initial growth rate was dependent on size of inoculum, growth rate variable and appeared to be related to the natural flora of the meat.

Staphylococcus aureus. Enterotoxigenic *Staphylococcus aureus* accounted for 19% of bacterial foodborne outbreaks in 1982 (MacDonald and Griffin, 1986). Foods frequently incriminated in staphylococcal foodborne illness include meat and meat products; poultry and egg

products; egg, tuna, chicken, potato and macaroni salads; cream-filled pastries, cream pies, and chocolate eclairs; sandwich fillings; and milk and dairy products (Bryan, 1985).

The optimum growth temperature for *S. aureus* is 35-40°C with enterotoxin production optimum between 40-45°C (Tatini, 1973) with reports showing *S. aureus* growth at temperatures as low as 5-10°C (Banwart, 1981). Laboratory criteria for determining an outbreak as the result of *S. aureus* is $\geq 10^5$ CFU/g (Bryan, 1985) and <1 ug enterotoxin/100 g from implicated food (Bergdoll, 1973).

Peanut butter, ham, tongue and chicken sandwiches were inoculated with staphylococci to test their ability to penetrate and grow in the bread (Kelly and Mack, 1935). Slow growth of enterotoxigenic staphylococci was reported in ham, tongue and chicken sandwiches held at 4.4 and 8°C but most rapidly at 37°C. Given a start in warmth, the staphylococci multiplied rapidly at 8°C. Thus, staphylococci can grow in bread when introduced by inoculation of the filler especially meat fillers with high levels of salt which is selective for staphylococci.

Pie filling was also inoculated with 2.5×10^4 cells/g *Micrococcus pyogenes* var. *aureus* and cooled at 5°C (refrigerator), 28.9°C (room temperature) and in standing water (not changed) with an initial temperature of 17°C, and running water at a temperature of 17°C (Miller, 1955). Counts increased under all conditions by 24 h with pie filling held at room temperature showing the greatest increase in *Micrococcus* populations.

Angelotti et al. (1961) incubated custard, chicken a la king and ham salad incubated with *S. aureus* at 2°C intervals from 4.4-10°C. In custard and chicken a la king *S. aureus* grew at >7.0°C. Growth took

2+ days for temperatures <10°C. In ham salad no growth was detected at 4.4-10°C. Thus, *S. aureus* can be prevented in perishable foods when the internal temperature is ≤7.0°C.

Enterotoxin production by *S. aureus* when inoculated into vanilla pudding was also reported (Scheuser and Harmon, 1973). Detectable amounts of toxin (10^6 CFU/g) were detected in samples incubated between 19 to 45°C. At 19°C, 50-84 h were required for sufficient toxic production; samples incubated at 37°C only required 15-22 h.

Yersinia enterocolitica. *Yersinia enterocolitica* can multiply in properly refrigerated foods (0-4°C). It grows at temperatures of 4-42°C with an optimum temperature of 28-29°C (Brenner, 1984). Foods that could be possible vehicles of *Yersinia enterocolitica* foodborne illness include meat, meat products, meat dishes, poultry, poultry products, poultry dishes, raw milk (Bryan, 1985), seafood (Peixotto et al., 1979), and tofu (soybean curd packed in water) (Aulisio et al., 1983). Laboratory criteria for determining an outbreak from Y. *enterocolitica* is 10^9 CFU/g from implicated food (Szita et al., 1973).

An outbreak in chocolate milk in New York State linked its presence in foods to human infections (Moustafa et al., 1983). More recently, the organism has caused an outbreak of illness associated with pasteurized milk presumably contaminated with the organism after pasteurization (Sellers, 1983), reconstituted powdered milk and turkey chow mein (Proceedings of the Second National Conference for Food Protection, 1984), and tofu contaminated by the use of non-chlorinated spring water in the producer processing waters (Aulisio et al., 1983).

Chapter III

MATERIALS AND METHODS

Conceptual framework

A Michigan State University (M.S.U.) sanitarian reported that temperatures of foods were often >7.2°C during CHSS (Wernette, 1985). Since salad bar items, the most common items held on a cold-serving unit, have been increasingly reported as a source of foodborne disease, CHSS could be potentially hazardous. After reviewing the literature, limited information on temperature and microbiological guidelines for CHSS was found. Therefore, a study was completed to evaluate the effectiveness of a cold-serving unit using the determinants of time-temperature patterns and total bacterial plate counts.

Time-temperature patterns and total bacterial plate counts were monitored in triplicate in a laboratory and once at each of three field sites for four experimental products. Three M.S.U. foodservice operations (Brody Complex, McDonel Hall, and Wonders Hall cafeterias), were assigned by the Department of Foodservice and used as field sites.

Four experimental products were observed during CHSS to obtain information on a range of food items. All experimental products were

held on a cold-serving unit a) in a laboratory for 24 h for an intensive examination under abusive time conditions and b) at three field sites for 4 h, the length of service of one meal in an M.S.U. foodservice operation. Products chosen (i.e., bulk cottage cheese, portioned cottage cheese, portioned tuna salad, and deviled eggs) were defined as potentially hazardous (FDA, 1986) and were common items held on a cold-serving unit in foodservice operations. Bulk and portioned cottage cheese were monitored to compare the effect of volume on time-temperature patterns and total bacterial plate counts. Product volume, dish and container size were consistent with procedures in M.S.U. residence hall foodservice operations. Portioned products were covered with Saran Wrap^{TM} plastic film and bulk cottage cheese was covered with the a lid to prevent drying and mold growth; this was not practiced in M.S.U. foodservice operations.

Time-temperature measurements and total bacterial plate counts were taken at 0, 2, 4, 8, 16, and 24 h in the laboratory and at 0, 2, and 4 h in field sites. Temperature measurements and samples for bacterial plate counts were taken at 2.5 cm depths in the surface center of all products. This was assumed to be the warmest point of the food items and thus would show the highest temperatures and largest microbiological populations.

Experimental products: Laboratory and field

The three experimental products and their respective product description and/or recipe formulation (by percentage of total weight) are shown below (Michigan State University, 1986).

1. Cottage cheese, 2.3 kg. Roelof's 4% milkfat, Grade A pasteurized (Roelof Dairy, Inc., Galesburg, MI) portioned and bulk samples.

2. Tuna Salad: light tuna, drained, 49%; celery, chopped fine, 24%; salad dressing, 12%; pickle relish, drained, 12%; onions, chopped fine, 2%; realemon, 1%; salt, 0.06%; black pepper, 0.0003%

3. Deviled eggs: cooked eggs cut in half, 88%; mayonnaise, 11%; prepared mustard, 1%; paprika, 0.003%; salt, 0.0004%.

All products were prepared and/or purchased from McDonel Hall cafeteria to ensure consistency in preparation and storage procedures. Products were transported to the laboratory in a 30 cm x 60 cm insulated container (Coleman, Wichita, KS) at $\geq 0^{o}C$. No product was prepared and/or purchased ≥ 4 h prior to holding on a cold-serving unit to minimize the potential for post-processing contamination.

Portioned samples: Laboratory and Field. One-hundred gram samples (100 ± 1 g) were weighed on a Galaxy^{TM} scale (G4000-DC; Ohaus Scale Corp., Florham Park, NJ) into a sanitized #8 scoop (Hamilton Beach, Washington, NC) and placed into sanitized vegetable dishes (N = 10) (BO-43; Shenango China, New Castle, PA) obtained from an M.S.U. residence hall foodservice operation. Prior to portioning dishware was washed with 120 ml Liqui-Nox (Alconox, Inc., New York, NY) per 18 L of hot water, rinsed with hot water, soaked in sanitizing solution for 5 minutes, and air-dried prior to each sampling period (0-4 h or 0-24 h). Each portioned sample was covered with Saran Wrap^{TM} plastic film (40 m x 29 cm; Dow Chemical Co., Indianapolis, IN). All samples were portioned in the laboratory and when necessary carried to field sites in a 30 cm x 60 cm insulated container (Coleman, Wichita, KS) at ($\geq 0^{o}C$) holding.

Bulk samples: Laboratory and Field. Two 2.27 kg ± 0.1 samples of cottage cheese were taken from two separate containers (2.3 kg ± 0.1 wt/container) of cottage cheese and held in two 20 cm deep plastic crock pots (C.P.-2.7; Cambro, Huntington Beach, CA) obtained from an M.S.U. residence hall foodservice operation. Prior to the sampling period (0-4 h or 0-24 h) both containers were washed with Liqui-Nox, rinsed with hot water, soaked in sanitizing solution for 5 minutes, and air-dried.

Equipment: Laboratory

A Precision^{R} (Model No. BLC-4-BU; Precision Metal Products, Inc., Miami, FL) cold-serving unit on loan from Brody Complex cafeteria was used for cold-holding products in the laboratory. The cold-serving unit in the laboratory used ice and mechanical cooling to maintain cold temperatures.

Thirty minutes (30 min) prior to 0 time sampling, the cold-serving unit was turned on (no temperature controls were available on the equipment used in the laboratory or field sites). The stainless steel basin was wiped with sanitizing solution [(30 ml of Mikro Quat^{R} (Economics Laboratory, Inc., St. Paul, MN) per 11 L of hot water] and lined with two plastic bags (56 cm x 51 cm x 122 cm; Stone Container Corporation, North Chicago, IL) held together with masking tape. Plastic bags were used because the cold-serving unit in the laboratory did not have an operating drain, therefore, the plastic bags were used for ease in cleaning. Fifteen minutes (15 min) before 0 h sampling, 22.5 kg ± 0.1 of potable crushed ice (1.6 cm x 2 cm) was placed into the lined basin and distributed equally to form a flat surface of ice.

Ice was used in the laboratory procedure because initial instructions from an M.S.U. Residence Hall foodservice operation indicated that ice and mechanical cooling was commonly used in residence hall foodservice operations for CHSS.

Equipment: Field

Experimental products monitored in field sites were held on cold-serving units in Brody Complex, McDonel Hall and Wonders Hall cafeterias. Manufacturers and models of cold-serving units are listed in Table 2. Cold-serving units used in field sites maintained cold temperatures by mechanical cooling and did not use ice. The space assigned on the cold-serving units in the three field sites used only mechanical cooling during CHSS. The equipment at the field site also had an increased load factor (approximately 75%) because it was holding foods for self-service during experimental holding times.

Temperature recording: Laboratory and field

A Digital Heat-Prober^{TM} thermometer (Model No. 350XC; Wahl Instruments, Inc., Culver City, CA) with probe (P/N 202-Immersion, William Wahl Corporation, Los Angeles, CA) was calibrated 2 h prior to temperature measurements. A thermos (Bottle No. 2442; King Seeley Thermos Co., Norwich, CT) was filled with 0.5 L $\pm$ 0.01 potable crushed ice and water. After the ice and water stabilized (4-5 min), 2.5 cm of the thermometer stem was immersed away from the bottom and sides of the thermos, and the thermometer calibrated to 0^{o}C (NSF, 1979).

Prior to each sampling period (0-4 h or 0-24 h), the thermometer stem was washed with Liqui-Nox, rinsed in hot water, immersed in

Table 2. Models and manufacturers of cold-serving units used to hold experimental products in the study on the effectiveness of cold-serving units.

Location	Model	Manufacturer and Address
I. Michigan State University Residence Halls		
Brody Cafeteria	BC-88R	Carter-Hoffman Corp. Mundelein, IL
McDonel Hall	BC-88R	Carter-Hoffman Corp. Mundelein, IL
Wonders Hall	BC-76B	Carter-Hoffman Corp. Mundelein, IL
II. Food Science Laboratory	BL-4-BU	Precision Metal Products, Inc. Miami, FL

sanitizing solution for 5 min, and allowed to air-dry. Ethyl alcohol (Absolute 200 Proof; AAPER Alcohol & Chemical Co., Shelbyville, KY) was used to clean the stem between temperature probes during one sampling period (0-4 h or 0-24 h). Product temperatures were taken at 0, 2, 4, 8, 16, and 24 h after foods were placed on the cold-serving unit in the laboratory and at 0, 2, and 4 h after placement on cold-serving unit in the field sites. Temperatures were measured at 2.5 cm depths in the surface center for both bulk and portioned experimental products. The temperature was allowed to stabilize for 60 sec before reading measurement. The same individual recorded temperatures of all samples during the study.

Microbiological analysis

Sampling time: Laboratory. Two randomly selected samples (N=12) of each experimental product were analyzed for total bacterial plate count (a) immediately prior to placement on the cold-serving unit (0 h) and (b) 2, 4, 8, 16, 24 h after placement on the cold-serving unit. The procedure was performed in triplicate in the laboratory to acquire representative data for statistical analyses.

Sampling time: Field. Two randomly selected samples of each experimental product (N=6) were analyzed for total bacterial plate count (a) immediately prior to placement on cold-serving unit (0 h) and (b) 2 and 4 h after placement on cold-serving unit. The procedure was performed for each experimental product in triplicate, once at each field site.

Product samples: Laboratory. Samples for microbiological analyses were aseptically taken from the surface center of the

product, weighed in 25 g ± 0.1 g aliquots, and placed in sterile Stomacher^{R} Lab-Blender Bags (7" x 12"; Seward Laboratories, London, England). Two 25 g samples taken from the original product container were weighed and used as 0 h sample for temperature measurements and total bacterial plate count in the laboratory.

Product samples; Field. Microbiological samples were aseptically taken from the surface center of the product and weighed in 25 g ± 0.1 g aliquots, placed in sterile sealed Whirl-pak bags, surrounded with potable crushed ice, and maintained in a 30 cm x 60 cm insulated container (Coleman, Wichita, KS) at 0°C during collection, storage, and transportation to the laboratory (Bryan, 1985). In field sites, a randomly selected portioned sample transported to the field site was used as 0 h sample immediately after placing all samples on the cold-serving unit. Microbiological analyses of field site samples never exceeded 8 h after sampling.

Plating; Laboratory and field. A 1:10 serial dilution to 10^{-5} for cottage cheese samples and to 10^{-6} for deviled eggs and tuna salad samples was prepared by adding 225 ml of 0.1% peptone water to each 25 g sample. The initial dilution was placed in a Stomacher Lab Blender 400 (Model No. STO-400; Tekmar Company, Cincinnati, OH) for 3 min at low speed (8000 rpm). A 0.1 ml inoculum of dilutions at 10^{-4} and 10^{-5} for cottage cheese samples and 10^{-5} and 10^{-6} for deviled eggs and tuna salad samples were spread plate onto eight plates of non-selective media. Non-selective media was 3% trypticase soy broth (Becton Dickenson and Co., Cockeysville, MD), 1.5% bacto-agar (Difco Laboratories, Detroit, MI), and 95.5% distilled water. Four plates were incubated at 7°C for 10 days for psychrotrophic aerobic plate

counts (Gilliland, 1976), and four plates were incubated at 32°C for 48 h ± 3 h for mesophilic aerobic plate counts (Gilliland, 1976).

Criteria for acceptability: Laboratory and field

Experimental products were evaluated using microbiological guidelines for mesophilic aerobic plate counts of $\leq 10^5$ CFU/g (Hobbs and Gilbert, 1970; Fowler et al., 1973). Counts $\leq 10^5$ CFU/g were also used to evaluate psychrotrophic aerobic plate counts. Product deterioration has been reported to occur when psychrotrophic counts reach approximately 10^6 to 10^8 CFU/g (ICSMF, 1980), thus the assumption was made that deterioration due to psychrotrophic bacteria at $\leq 10^5$ CFU/g would be little or none at all. Temperature compliance was indicated as measurements of ≤7.2°C in the laboratory (0-24 h) and in field sites (0-4 h) (USDHEW, 1978).

Statistical analysis: Laboratory and field

Temperature measurements (N=216) and mesophilic (N=216) and psychrotrophic (N=216) aerobic plate counts were performed in triplicate in the laboratory (12 days or 288 h) and once at each field sites (12 days or 48 h) for all experimental products.

Statistical Package for the Social Sciences/Personal Computer version (SPSS/PC) (Release 1.1 update, SPSS, Inc., Chicago, IL) was used for all statistical analyses. The mean (X) was defined as:

$$X = \frac{X_i}{N}$$

Standard deviation (s):

$$s = \frac{(X_i - X)^2}{N - 1}$$

Standard error of the mean (SEM):

$$SEM = \frac{s}{N}$$

where N is the number of samples and X_i is the value of the variable for the *i*th case.

In situations where plates were too numerous to count, missing values were recorded. Therefore, the N value for calculating the mean, s, and SEM may differ among experimental products and/or sampling times. Where plates showed no growth, a value of 1 multiplied by the corresponding lowest dilution was used as an estimated aerobic plate count (Brazis et al., 1972).

Correlation coefficient (r) was calculated to determine the strength of the linear relationship between mesophilic populations and time, psychrotrophic populations and time, mesophilic populations and product temperature, psychrotrophic populations and product temperature, product temperature and time, and product temperature and room temperature. Correlations coefficients were calculated to 8 h in the laboratory and to 4 h in field sites. The correlation coefficient (r) was defined as:

$$r = \frac{(X_i - X)(Y_i - Y)}{(N - 1)S_X S_Y}$$

where: N is the number of samples and S_X and S_Y are the standard deviations of the two variables (SPSS, Inc., 1984).

Linear regression analyses included comparing mesophilic populations and time, psychrotrophic populations and time, mesophilic populations and product temperature, psychrotrophic populations and product temperature, product temperature and time, and product temperature and room temperature. Linear regression was calculated to 8 h in the laboratory and to 4 h in field sites. Linear regression

analyses included the regression equation, r^2, and level of significance of the slope. The regression equation was defined as:

$$Y = B_o + B_1X$$

where B_o = intercept value of Y when X = 0 and B_1 = the slope change in Y per unit change in X.

A t-test for significance of mean differences between bulk and portioned cottage cheese ($t = (d - u_d)/s_d$) was calculated to compare product temperature, mesophilic and psychrotrophic populations.

Levels of significance for all statistical analyses were indicated as 0.05 (significant), 0.01 (very significant), and 0.001 (highly significant).

Chapter IV

RESULTS

Data in this chapter were based on temperature measurements and mesophilic and psychrotrophic aerobic counts of four experimental products held on a cold-serving unit in a laboratory and three field sites. Two-hundred sixteen (216) samples (144 in a laboratory and 72 in field sites) were monitored and statistically analyzed. Analyses for each product included calculation of mean, standard deviation, standard error of the mean, linear correlation and regression, and a t-test to compare differences between bulk and portioned cottage cheese. Missing data resulted in differing N values. Correlation and linear regression analyses was calculated until 8 h for laboratory samples because data collected after 8 h was constant. Analyses was calculated until 4 h for field samples.

Product temperature: Laboratory

Of 144 temperature measurements of four products held on a cold-serving unit in a laboratory over 24 h, 75% of the measurements were >7.2°C (Hobbs and Gilbert, 1970; Fowler et al., 1973) and thus defined as non-compliant (see Appendix A, p. 1-8). Twenty-five percent (25%) of measurements at 0 h were >7.2°C, which was attributed to the time products were at room temperature for portioning. By 2 h, non-compliant temperature measurements had increased to 71% and remained

that way for 24 h.

Mean product temperatures, standard deviations and standard errors of the mean are reported in Table 3 for four experimental products held on a cold-serving unit in a laboratory for 24 h. Portioned cottage cheese (100 g/portion) at 0 h was 6.3°C with a standard deviation of 2.3°C. By 2 h the temperature increased to 7.5°C and again increased to 9.0°C by 8 h. At 16 h with less personnel working in the laboratory and the environmental temperatures decreasing (Appendix A, p. 1-2), temperature of portioned cottage cheese decreased to 7.5°C. However, at 24 h temperature increased to 8.6°C. Portioned tuna salad (100 g/portion) and deviled eggs (90 g ± 10 g/portion) also showed similar increases and decreases in temperature. In contrast, temperature of bulk cottage cheese (2.27 kg/portion) consistently increased from 0 to 24 h, with an initial temperature of 4.2°C and a final temperature of 11.8°C at 24 h.

Three of the four products held on a cold-serving unit in a laboratory showed temperatures <7.2°C at 0 h, i.e portioned cottage cheese (6.3°C), bulk cottage cheese (4.2°C), and deviled eggs (6.1°C) (Table 3; Figures 4a and 4b). Portioned tuna salad was the only product at 0 h that was >7.2°C (8.2°C). All products increased to >7.2°C by 2 h and did not decrease to ≤7.2°C during measurements in the 24 h period (Table 3). All products showed the greatest increase in temperature between 0 and 2 h.

Linear correlation and regression analyses of product temperature vs. time of four products held on a cold-serving unit in a laboratory for 24 h is summarized in Table 4. Bulk cottage cheese, portioned

Table 3. Laboratory Study: Mean[a] product temperature taken from the surface center of four experimental products held chilled on a cold-serving unit for 24 h.

Experimental Product and Weight	Hours					
	0	2	4	8	16	24
	- - - - - - - - - - - - - - - - °C ± SD (SEM) - - - - - - - - - - - - - - - -					
Cottage cheese[b], 100 g	6.3 ± 2.3 (0.9)[c]	7.5 ± 2.5 (1.0)	8.5 ± 1.4 (0.6)	9.0 ± 1.9 (0.8)	7.5 ± 2.4 (1.0)	8.6 ± 1.8 (0.8)
Cottage cheese, bulk 1.2 kg	4.2 ± 2.3 (0.9)	7.9 ± 1.7 (0.7)	9.6 ± 1.3 (0.5)	11.7 ± 1.9 (0.8)	11.7 ± 3.1 (1.3)	11.8 ± 2.9 (1.2)
Tuna salad[b], 100 g	8.2 ± 4.0 (1.6)	9.4 ± 2.7 (1.1)	9.8 ± 1.7 (0.7)	10.9 ± 1.6 (0.7)	9.5 ± 1.9 (0.8)	10.0 ± 1.4 (0.6)
Deviled eggs[d], halves 100 ± 10 g	6.1 ± 1.4 (0.6)	9.1 ± 1.1 (0.5)	9.0 ± 2.3 (0.9)	8.9 ± 1.2 (0.5)	8.9 ± 1.4 (0.6).	9.3 ± 1.7 (0.7)

[a] N = 6; ± standard deviation; (standard error of the mean);
[b] Portioned in a laboratory
[c] Standard error of the mean
[d] White and yolk salad

Table 4. Laboratory study: Linear correlation and regression analyses[a] of product temperature vs. time for four products held on a cold-serving unit in a laboratory for 24 h.

Experimental Product	Number of samples	Regression equation	r	r^2	Level of significance
Cottage cheese, portioned	24	Y = 6.7 + 0.324(X)	.45	.202	$p<0.05$
Cottage cheese, bulk	24	Y = 5.2 + 0.888(X)	.81	.656	$p<0.001$
Tuna salad, portioned	24	Y = 8.4 + 0.321(X)	.36	.131	n.s.[b]
Deviled eggs, halves	24	Y = 7.3 + 0.277(X)	.43	.183	$p<0.05$

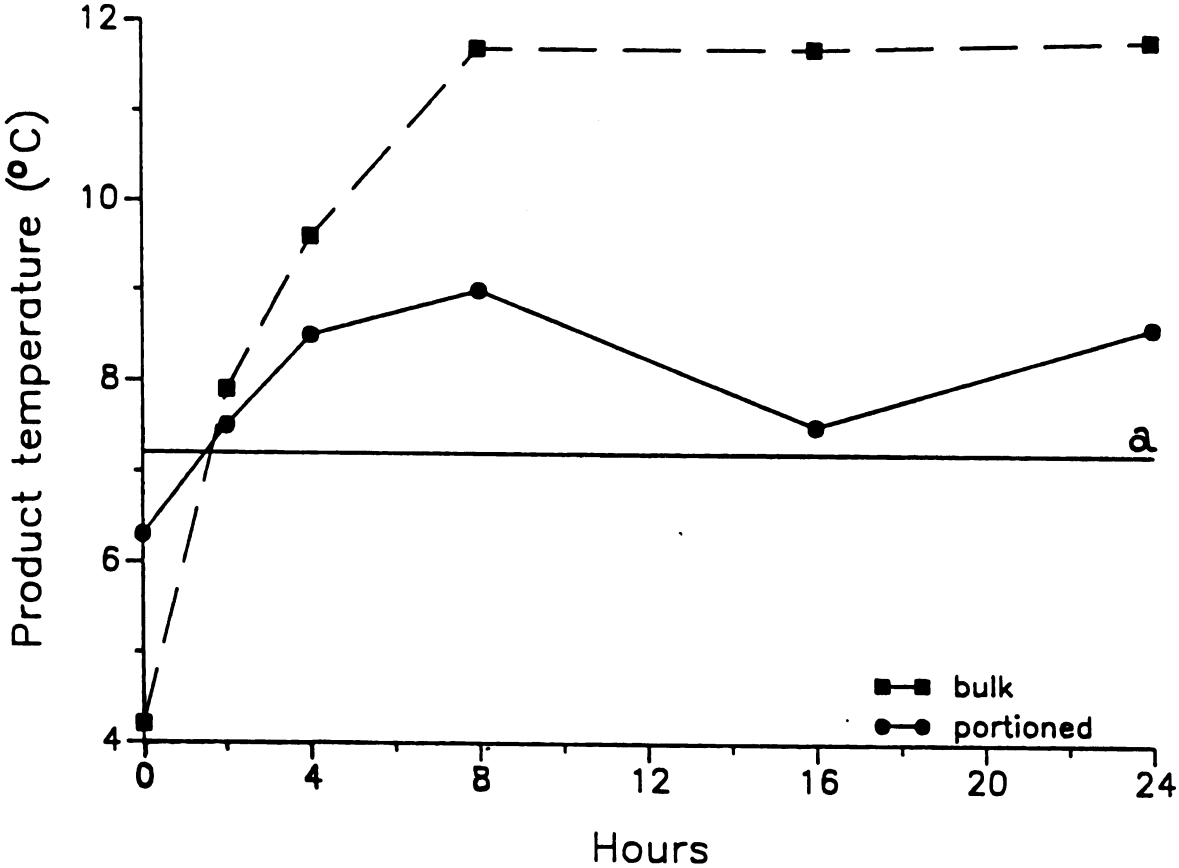
[a] Analyses was calculated to 8 h because data collected after 8 h was constant.

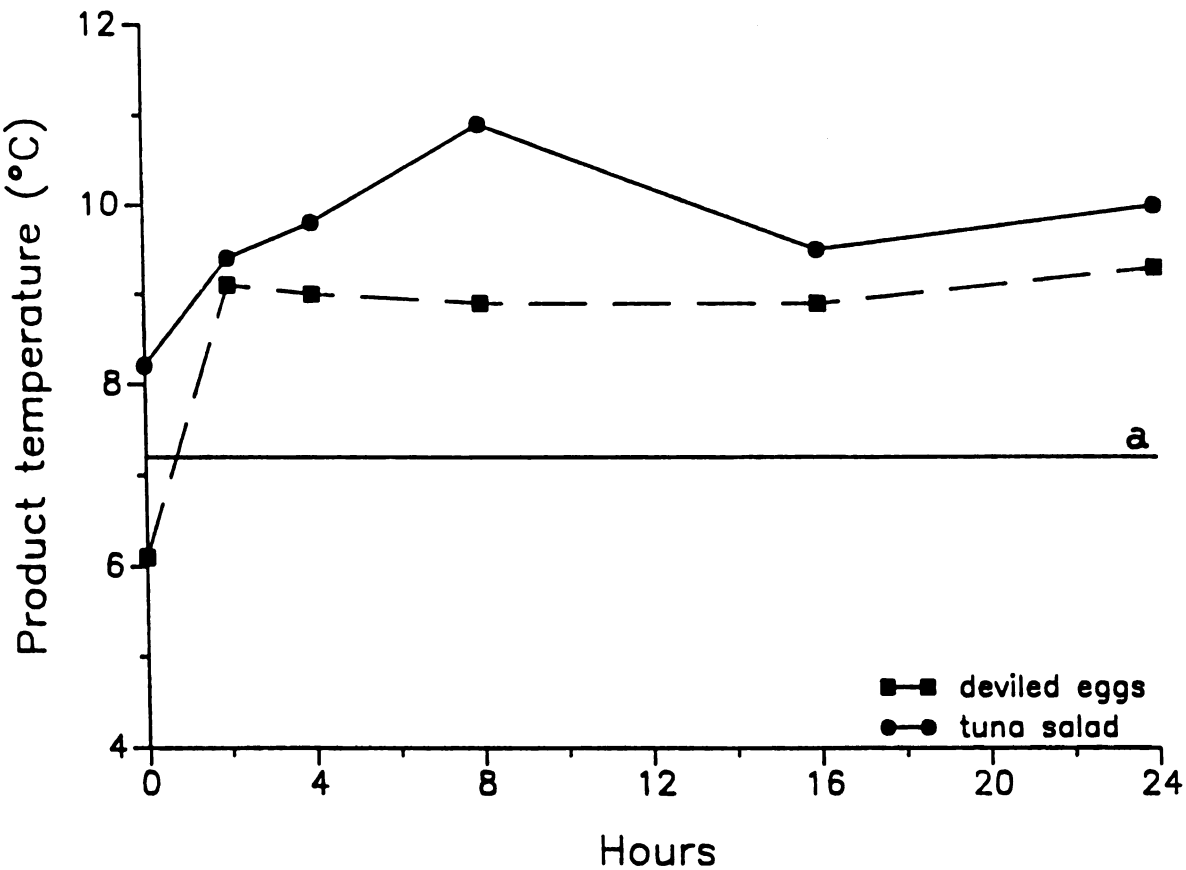
[b] n.s. = not significant

Figure 4a. Laboratory study: Mean product temperature (^{o}C) of bulk and portioned cottage cheese held on a cold-serving unit in a laboratory for 24 h.

Figure 4b. Laboratory study: Mean product temperature (^{o}C) of deviled eggs and portioned tuna salad held on a cold-serving unit in a laboratory for 24 h.

[a] $7.2^{o}C$ is the maximum internal temperature of foods held in refrigerated storage (U.S. HEW, 1978). No specific recommendations were available for cold-holding for self-service.


Product temperature (°C)
12
10
8
6
4
a
bulk
portioned
0
4
8
12
16
20
24
Hours


Product temperature (°C)
12
10
8
6
4
a
deviled eggs
tuna salad
0
4
8
12
16
20
24
Hours

cottage cheese and deviled eggs showed a significant increase in product temperature over time ($r=.81$, $p<0.001$; $r=.45$, $p<0.05$; $r=.43$, $p<0.05$, respectively). Portioned tuna salad showed a lack of significance between product temperature and time.

Linear correlation and regression analyses of product temperature and room temperature in the laboratory at $\geq$95% level are shown in Table 5. Bulk cottage cheese and portioned tuna salad showed significant increases ($r=.5$, $p<0.01$; $r=.55$, $p<0.01$, respectively). Portioned cottage cheese and deviled eggs showed no significant linear correlation or regression between product temperature and room temperature.

Product temperature: Field

Forty-six percent (46%) (N=72) of temperature measurements of four products held on a cold-serving unit in three field sites for 4 h, were >7.2°C (USDHEW, 1978) (see Appendix A, p. 1-8). At 0 h, 58% were >7.2°C which was the highest percentage of non-compliant temperatures. By 2 h only 38% (N=27) were non-compliant.

Table 6 presents mean product temperatures, standard deviations and standard errors of the mean of four experimental products held on a cold-serving unit in three field sites for 4 h. Portioned cottage cheese showed a mean temperature of 8.3°C at 0 h. By 2 h the temperature decreased to 5.6°C, and at 4 h to 4.6°C. Portioned tuna salad also showed a consistent decrease in temperature. Deviled eggs at 0 h showed a temperature of 11.1°C and decreased to 6.4°C at 2 h. The temperature increased slightly at 4 h to 6.5°C. The temperature of bulk cottage cheese consistently increased from 0 to 4 h (Table 6).

Table 5. Laboratory study: Linear correlation and regression analyses[a] of product temperature vs. room temperature for four products held on a cold-serving unit in a laboratory for 24 h.

Experimental Product	Number of samples	Regression equation	r	r^2	Level of significance
Cottage cheese, portioned	24	Y = -4.42 + 0.542(X)	.39	.153	n.s.[b]
Cottage cheese, bulk	24	Y = -67.43 + 3.206(X)	.58	.341	$p<0.01$
Tuna salad, portioned	24	Y = -23.34 + 1.437(X)	.55	.298	$p<0.01$
Deviled eggs, halves	24	Y = -4.39 + 0.537(X)	.29	.085	n.s.

[a] Analyses was calculated to 8 h because data collected after 8 h was constant.

[b] n.s. = not significant

Table 6. Field Study: Mean[a] product temperature taken from the surface center of four experimental products held chilled on a cold-serving unit in three field sites for 4 h.

Experimental Product and Weight	Hours		
	0	2	4
	- - - - - - - - °C + SD (SEM) - - - - - - -		
Cottage cheese,[b] 100 g	8.3 ± 2.5 (1.0)[c]	5.6 ± 1.6 (0.7)	4.6 ± 2.2 (0.9)
Cottage cheese, bulk 1.2 kg	5.9 ± 1.3 (0.5)	9.4 ± 1.4 (0.6)	11.3 ± 1.9 (0.8)
Tuna salad,[b] 100 g	10.5 ± 3.1 (1.3)	6.5 ± 1.1 (0.5)	5.6 ± 1.2 (0.5)
Deviled eggs[d], halves 100 + 10 g	11.1 ± 2.3 (0.9)	6.4 ± 3.1 (1.3)	6.5 ± 2.4 (1.0)

[a] N = 6; ± standard deviation (standard error of the mean)
[b] Portioned in a laboratory
[c] Standard error of the mean
[d] White and yolk salad

The overall decrease in portioned products was attributed to the cooling medium used in the three field sites which will be discussed in more detail in Chapter V.

Portioned products at 0 h were >7.2°C (Table 6; Figures 5a and 5b), whereas, temperature of bulk cottage cheese was <7.2°C (5.9°C) (Table 6; Figure 5a). The temperature of all portioned products decreased to <7.2°C by 2 h and did not increase to ≥7.2°C over 4 h. Temperature of bulk cottage cheese, however, increased to 9.2°C by 2 h and never decreased to ≤7.2°C by 4 h. Portioned products showed the greatest decrease in temperature between 0 and 2 h; bulk cottage cheese showed the greatest increase in temperature between 0 and 2 h.

Linear correlation and regression analyses of product temperature vs. time at ≥95% level for four experimental products held on a cold-serving unit in three field sites for 4 h is reported in Table 7. Portioned cottage cheese, portioned tuna salad, and deviled eggs showed a significant decrease in temperature ($r=-.60$, $p<0.01$; $r=-.72$, $p<0.001$; $r=-.56$, $p<0.05$, respectively), whereas bulk cottage cheese showed a significant increase in temperature over time ($r=.83$, $p<0.001$).

Linear correlation and regression analyses of product temperature vs. room temperature at ≥95% level for the four experimental products held on a cold-serving unit in three field sites for 4 h is summarized in Table 8. All portioned products showed a lack of linear correlation and regression between product temperature and room temperature. Bulk cottage cheese showed a significant increase in product temperature as room temperature increased ($r=.74$, $p<0.001$).

Table 7. Field study: Linear correlation and regression analyses of product temperature vs. time for four products held on a cold-serving unit in three field sites for 4 h.

Experimental Product	Number of samples	Regression equation	r	r^2	Level of significance
Cottage cheese, portioned	18	Y = 7.98 + -0.92(X)	-.60	.3630	p <0.01
Cottage cheese, bulk	18	Y = 6.16 + 1.36(X)	.83	.6962	p<0.0001
Tuna salad, portioned	18	Y = 10.00 + -1.23(X)	-.72	.5114	p<0.001
Deviled eggs, halves	18	Y = 10.26 + -1.15(X)	-.56	.3191	p<0.05

Table 8. Field study: Linear correlation and regression analyses of product temperature vs. room temperature for four products held on a cold-serving unit in three field sites for 4 h.

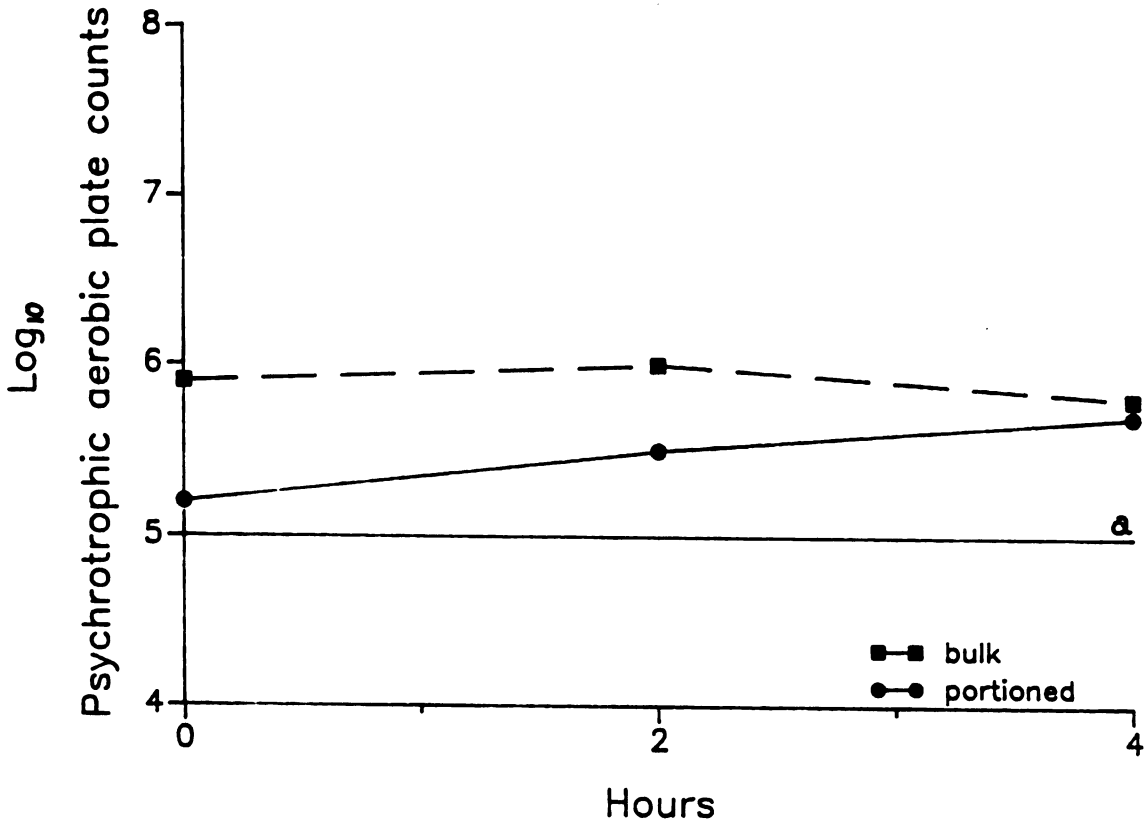
Experimental Product	Number of samples	Regression equation	r	r^2	Level of significance
Cottage cheese, portioned	18	Y = 25.55 + -0.88(X)	-.46	.2162	n.s.[a]
Cottage cheese, bulk	18	Y = -15.85 + 1.05(X)	.74	.5435	p<0.001
Tuna salad, portioned	18	Y = 59.02 + -2.33(X)	-.42	.1764	n.s.
Deviled eggs, halves	18	Y = 3.79 + 0.18(X)	.12	.0137	n.s.

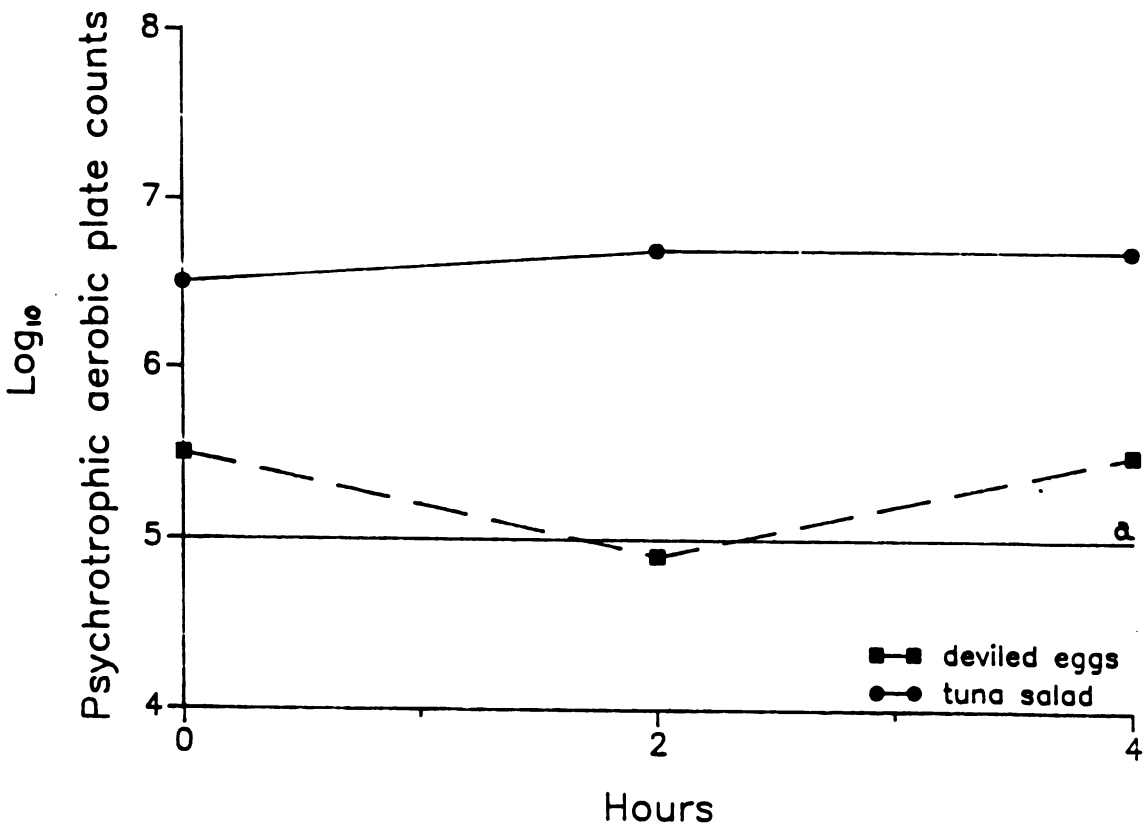
[a] n.s. = not significant

Figure 5a. Field study: Mean product temperature (^{o}C) of bulk and portioned cottage cheese held on a cold-serving unit in three field sites for 4 h.

Figure 5b. Field study: Mean product temperature (^{o}C) of deviled eggs and portioned tuna salad held on a cold-serving unit in three field sites for 4 h.

[a] $7.2^{o}C$ is the maximum internal temperature of foods held in refrigerated storage (U.S. HEW, 1978). No specific recommendations were available for cold-holding for self-service.


Log10 Psychrotrophic aerobic plate counts
8
7
6
5
4
0
2
4
Hours
a
bulk
portioned


Log10 Psychrotrophic aerobic plate counts
8
7
6
5
4
0
2
4
Hours
a
deviled eggs
tuna salad

Mesophilic aerobic plate counts: Laboratory

One-hundred percent (100%) of 144 samples taken over 24 h in a laboratory showed mesophilic aerobic plate counts $>10^5$ CFU/g (see Appendix A, p. 1-8). Microbiological guidelines (Hobbs and Gilbert, 1970; Fowler et al., 1973) recommend that salads and salad items with total plate counts $\leq 10^5$ CFU/g be considered microbiologically safe. Using this standard all samples taken would have been considered not safe for consumption.

Table 9 presents the mean $\log_{10}$ of mesophilic aerobic counts of four products held on a cold-serving unit in a laboratory for 24 h. Portioned cottage cheese at 0 h showed a mean $\log_{10}$ of counts equal to 6.6 ± 0.5. Over the 24 h, the bacterial population decreased (2 h), increased twice (4,8 h), and decreased twice (16,24 h). At 24 h the mesophilic population had decreased from 0 h. Bulk cottage cheese, portioned tuna salad, and deviled eggs also showed increase and decreases in counts over 24 h (Table 9; Figures 6a and 6b). Increases and decreases in counts over time was attributed to lack of control in product preparation, possible differences in food composition among batches, differences in age of cottage cheese (Emmons, 1963), and laboratory error.

Linear correlation and regression analyses of $\log_{10}$ mesophilic aerobic counts and time at $\geq$95% level for four products held in a laboratory for 24 h are reported in Table 10. Mesophilic population in bulk cottage cheese, portioned cottage cheese and tuna salad showed a lack of significance, whereas deviled eggs showed a significant decrease ($r=-.51$, $p<0.05$).

Table 9. Laboratory study: Mean[a] of log_{10} mesophilic aerobic counts taken from the surface center of four experimental products held chilled on a cold-serving unit for 24 h.

Experimental Product and Weight	Hours					
	0	2	4	8	16	24
	Mean log_{10} of CFU/g[b] + SD (SEM)					
Cottage cheese[c], 100 g	6.6 ± 0.5 (0.2)[d]	6.2 ± 0.2[e] (0.1)	6.3 ± 0.2[f] (0.1)	6.7 ± 0.6 (0.2)	6.5 ± 0.5 (0.2)	6.3 ± 0.5 (0.2)
Cottage cheese, bulk 1.2 kg	6.7 + 0.1[e] (0.04)	6.4 + 0.3 (0.1)	6.4 + 0.3 (0.1)	6.7 + 0.5[e] (0.2)	6.7 + 0.4[e] (0.2)	6.8 + 0.6 (0.2)
Tuna salad[e], 100 g	8.0 + 0.3[e] (0.1)	7.9 + 0.5 (0.2)	7.9 + 0.2[e] (0.1)	7.9 + 0.2[f] (0.1)	7.6 + 0.2[e] (0.1)	7.7 + 0.1 (0.04)
Deviled eggs[f], halves 100 + 10 g	7.0 + 0.5 (0.2)	6.1 + 0.3[f] (0.1)	6.2 + 0.4[f] (0.2)	6.1 + 0.7[e] (0.3)	6.1 + 0.5[f] (0.2)	6.6 + 0.3[f] (0.1)

[a] N = 6, ± standard deviation; (standard error of the mean)
[b] CFU/g = colony forming units per gram
[c] Portioned in a laboratory
[d] Standard error of the mean
[e] N = 5
[f] N = 4
[g] White and yolk salad

Table 10. Laboratory study: Linear correlation and regression analyses[a] of $\log_{10}$ mesophilic aerobic plate counts vs. time for four products held on a cold-serving unit in a laboratory for 24 h.

Experimental Product	Number of samples	Regression equation	r	r^2	Level of significance
Cottage cheese, portioned	22	Y = 6.4 + 0.15(X)	.14	.020	n.s.[b]
Cottage cheese, bulk	22	Y = 6.5 + 0.01(X)	.06	.003	n.s.
Tuna salad, portioned	20	Y = 8.0 + -0.009(X)	-.09	.007	n.s.
Deviled eggs, halves	19	Y = 6.8 + -0.105(X)	-.51	.265	$p<0.05$

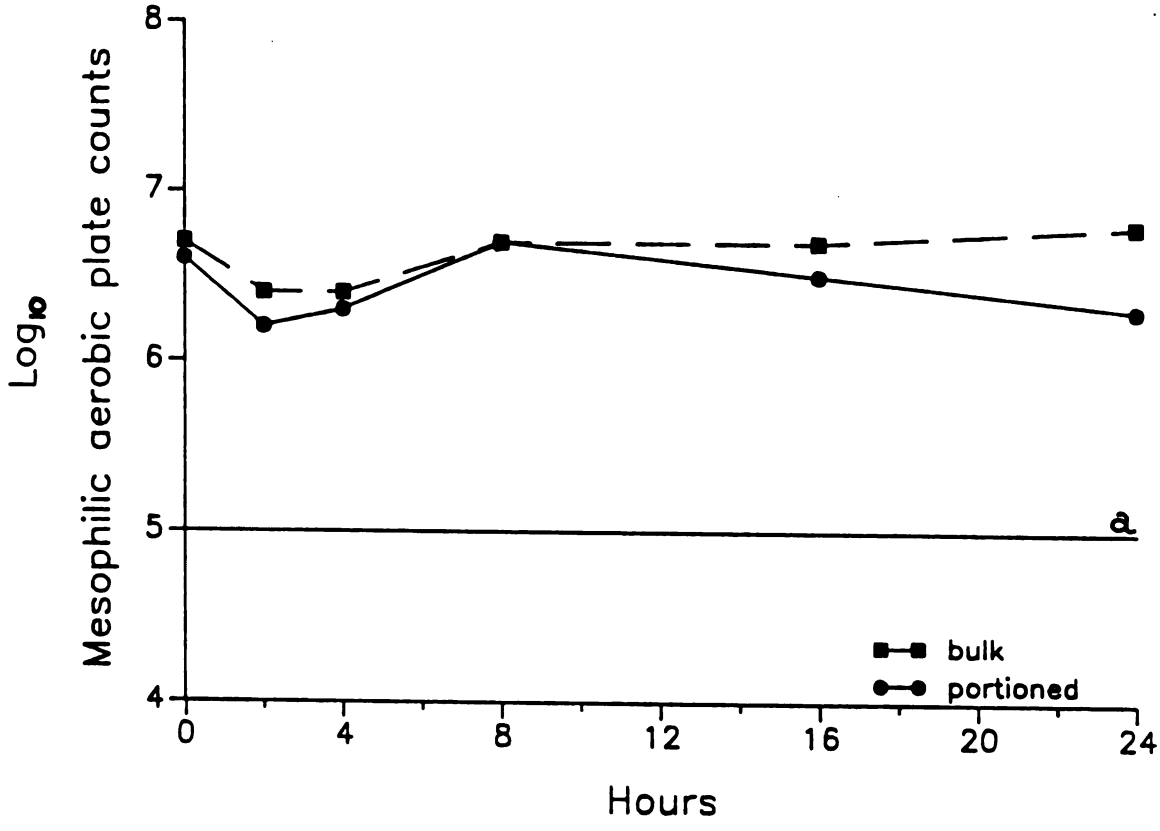
[a] Analyses was calculated to 8 h because data collected after 8 h was constant.

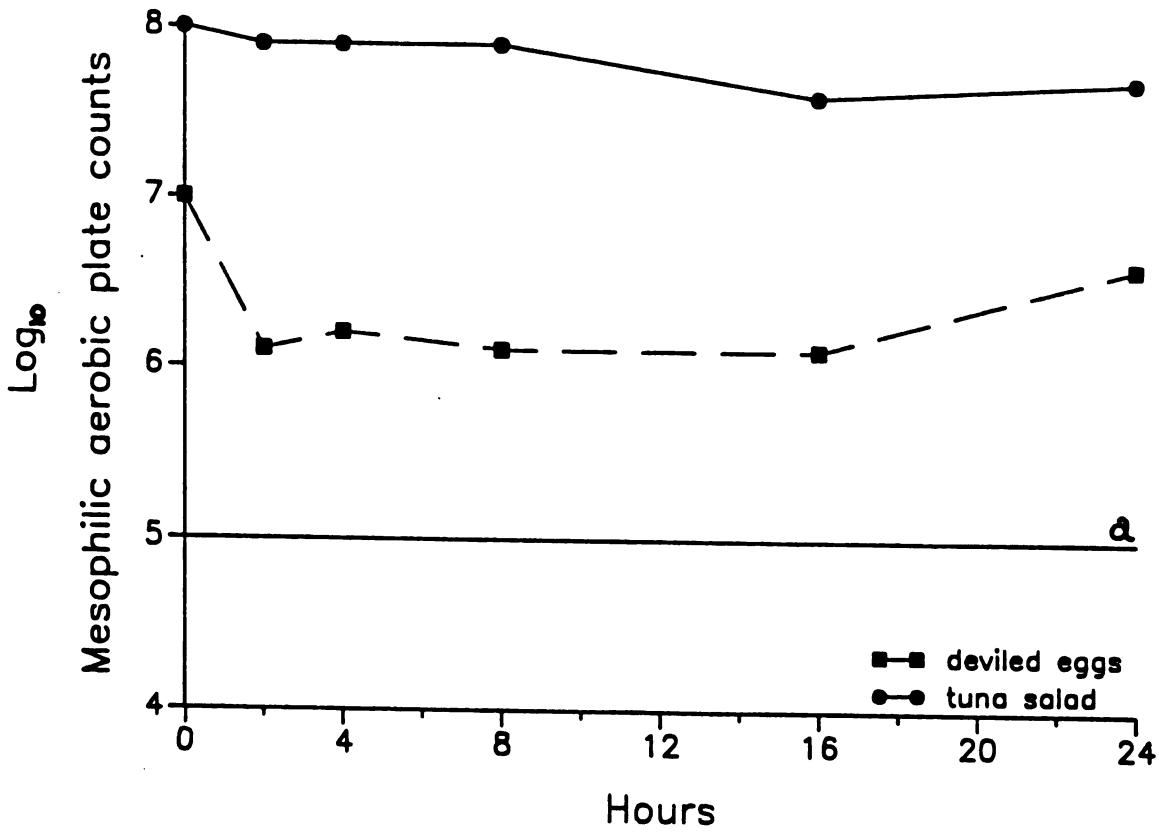
[b] n.s. = not significant

Figure 6a. Laboratory study: Mean of log mesophilic aerobic counts of bulk and portioned cottage cheese held on a cold-serving unit in a laboratory for 24 h.

Figure 6b. Laboratory study: Mean of log mesophilic aerobic counts of deviled eggs and portioned tuna salad held on a cold-serving unit in a laboratory for 24 h.

[a] 5 logs/g is the maximum mesophilic aerobic counts for salads and salad products (Hobbs and Gilbert, 1970; Fowler et al., 1973).


Log10 Mesophilic aerobic plate counts
8
7
6
5
4
a
bulk
portioned
0
4
8
12
16
20
24
Hours


Log10 Mesophilic aerobic plate counts
8
7
6
5
4
a
deviled eggs
tuna salad
0
4
8
12
16
20
24
Hours

Mesophilic aerobic counts: Field

One-hundred percent (100%) (N=72) of mesophilic bacterial plate counts of four experimental products taken over 4 h were $>10^5$ CFU/g (Fowler et al., 1973; Hobbs and Gilbert, 1970) (see Appendix A, p. 1-8).

Means were not calculated for deviled egg samples from field sites in Table 11 because only three (one each at 0, 2 and 4 h) of 18 samples were countable; others were too numerous too count. As reported in Chapter III, plates too numerous too count were recorded as missing values, thus there was insufficient data to calculate a representative mean.

Microbiological analyses of laboratory samples of deviled eggs used dilutions 10^{-5} and 10^{-6}, which resulted in plates between 30 and 300 CFU. However, samples of deviled eggs from field sites, which were analyzed after all laboratory samples, showed mesophilic plates that were too numerous too count for 15 of the 18 samples.

Table 11 presents the mean $\log_{10}$ of mesophilic aerobic counts of four experimental products held on a cold-serving unit in three field sites for 4 h. Portioned cottage cheese had mean $\log_{10}$ counts equal to 7.1 from 0-4 h (Table 11; Figure 7a)) Portioned tuna salad also showed a constant population over 4 h (Figure 7b). In contrast, populations in bulk cottage cheese decreased over 4 h (Figure 7a).

Table 12 presents the linear correlation and regression analyses of mesophilic aerobic counts vs. time at $\geq$95% level for experimental products held on a cold-serving unit in three field sites for 4 h. Growth was not significant in any product (Table 12).

Table 11. Field Study: Mean[a] $\log_{10}$ of mesophilic aerobic counts taken from the surface center of four experimental products held chilled on a cold-serving unit for 4 h.

Experimental Product and Weight	Hours		
	0	2	4
	- - Mean $\log_{10}$ of CFU/g[b] ± SD (SEM) - -		
Cottage cheese[c], 100 g	7.1 ± 0.3[d] (0.1)[e]	7.1 ± 0.2[f] (0.1)	7.1 ± 0.2[d] (0.1)
Cottage cheese, bulk 1.2 kg	6.9 ± 0.4[d] (0.2)	6.9 ± 0.3 (0.1)	6.6 ± 0.3[f] (0.1)
Tuna salad[c], 100 g	7.6 ± 0.2 (0.1)	7.6 ± 0.1 (0.04)	7.6 ± 0.2 (0.1)

[a] N = 6, ± standard deviation (standard error of the mean)
[b] CFU/g = colony forming unit per gram
[c] Portioned in a laboratory
[d] N = 5, ± standard deviation (standard error of the mean)
[e] Standard error of the mean
[f] N = 4, ± standard deviation (standard error of the mean)

Table 12. Field study: Linear correlation and regression analyses of $\log_{10}$ mesophilic aerobic plate counts vs. time for four products held on a cold-serving unit in three field sites for 4 h.

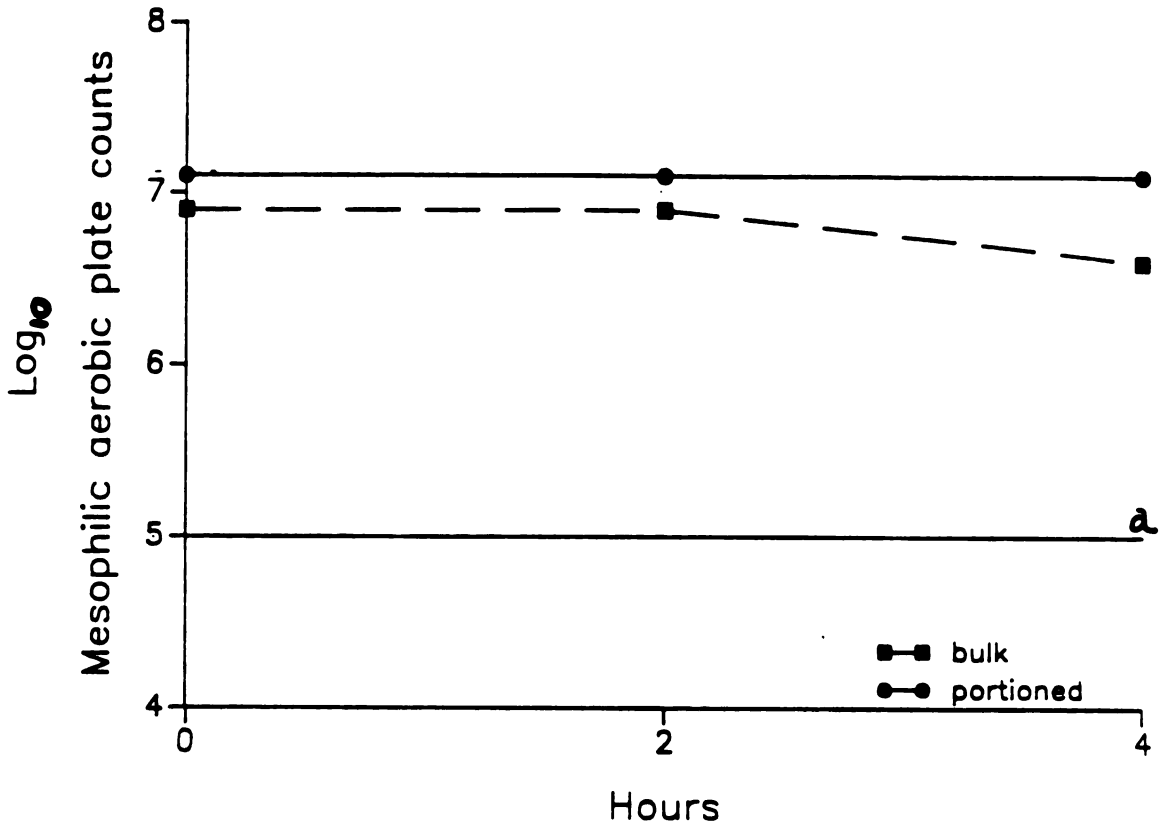
Experimental Product	Number of samples	Regression equation	r	r^2	Level of significance
Cottage cheese, portioned	14	Y = 7.1 + .006(X)	.05	.002	n.s.[a]
Cottage cheese, bulk	15	Y = 7.0 + -.072(X)	-.34	.115	n.s.
Tuna salad, portioned	18	Y = 7.6 + .005(X)	.04	.002	n.s.
Deviled eggs, halves	18	Y = 8.6 + -.060(X)	-.14	.019	n.s.

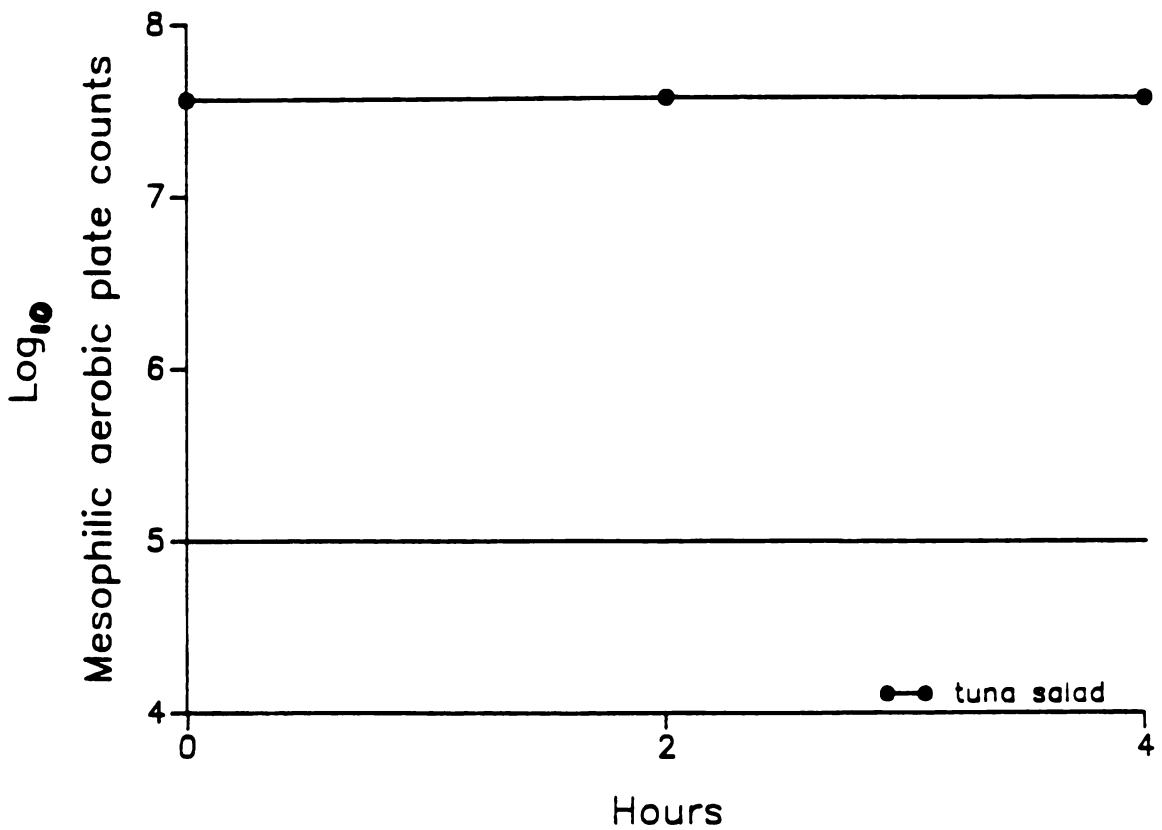
[a] n.s. = not significant

Figure 7a. Field study: Mean of log mesophilic aerobic counts of bulk and portioned cottage cheese held on a cold-serving unit in three field sites for 4 h.

Figure 7b. Field study: Mean of log mesophilic aerobic counts of portioned tuna salad held on a cold-serving unit in three field sites for 4 h.

[a] 5 logs/g is the maximum mesophilic aerobic counts for salads and salad products (Hobbs and Gilbert, 1970; Fowler et al., 1973).


Log10 Mesophilic aerobic plate counts
8
7
6
5
4
a
bulk
portioned
0
2
4
Hours


Log10 Mesophilic aerobic plate counts
8
7
6
5
4
tuna salad
0
2
4
Hours

Mesophilic aerobic counts vs. product temperature: Laboratory and Field

Tables 13 and 14 report the linear correlation and regression analyses of mesophilic aerobic counts vs. product temperature at ≥95% level in a laboratory and in three field sites. In the laboratory (Table 13) and field sites (Table 14) no product showed a significant linear correlation or regression between mesophilic aerobic counts and product temperature.

Psychrotrophic aerobic counts: Laboratory

Thirty-three percent (33%) (N=144) of samples taken over 24 h showed psychrotrophic aerobic counts $>10^5$ CFU/g (Hobbs and Gilbert, 1970; Fowler et al., 1973) (see Appendix A, p. 1-8). One-hundred percent (100%) of portioned tuna salad samples were non-compliant, whereas, only 0% of bulk cottage cheese samples, 7% of portioned cottage cheese samples, and 23% of deviled eggs samples were non-compliant.

Mean $\log_{10}$ of psychrotrophic aerobic counts of experimental products held on a cold-serving unit in a laboratory for 24 h are presented in Table 15. Portioned cottage cheese at 0 h had a mean $\log_{10}$ of psychrotrophic counts equal to 4.3 + 0.6; over 24 h bacterial counts did not consistently show an increase or a decrease (Table 15; Figure 8a). Bulk cottage cheese, portioned tuna salad and deviled eggs also showed similar inconsistencies in growth (Figure 8a and 8b). Inconsistency was attributed to lack of control in product preparation, possible differences in food composition among batches,

Table 13. Laboratory study: Linear correlation and regression analyses[a] of $\log_{10}$ mesophilic aerobic counts vs. product temperature for four products held on a cold-serving unit in a laboratory for 24 h.

Experimental Product	Number of samples	Regression equation	r	r^2	Level of significance
Cottage cheese, portioned	22	Y = 6.6 + -0.02(X)	-.11	.014	n.s.[b]
Cottage cheese, bulk	22	Y = 6.4 + 0.01(X)	.12	.012	n.s.
Tuna salad, portioned	20	Y = 7.4 + 0.020(X)	.17	.030	n.s.
Deviled eggs, halves	19	Y = 7.5 + -0.126(X)	-.42	.174	n.s.

[a] Analyses was calculated to 8 h because data collected after 8 h was constant.

[b] n.s. = not significant

Table 14. Field study: Linear correlation and regression analyses of $\log_{10}$ mesophilic aerobic plate counts vs. product temperature for four products held on a cold-serving unit in three field sites for 4 h.

Experimental Product	Number of samples	Regression equation	r	r^2	Level of significance
Cottage cheese, portioned	14	Y = 7.1 + 0.0002(X)	.002	.0000	n.s.[a]
Cottage cheese, bulk	15	Y = 6.7 + -0.112(X)	.094	.0088	n.s.
Tuna salad, portioned	18	Y = 7.8 + -0.028(X)	-.382	.1460	n.s.
Deviled eggs, halves	18	Y = 8.4 + 0.007(X)	.032	.0010	n.s.

[a] n.s. = not significant

Table 15. Laboratory Study: Mean[a] $\log_{10}$ of psychrotrophic aerobic counts taken from the surface center of foods held on a cold-serving unit for 24 h.

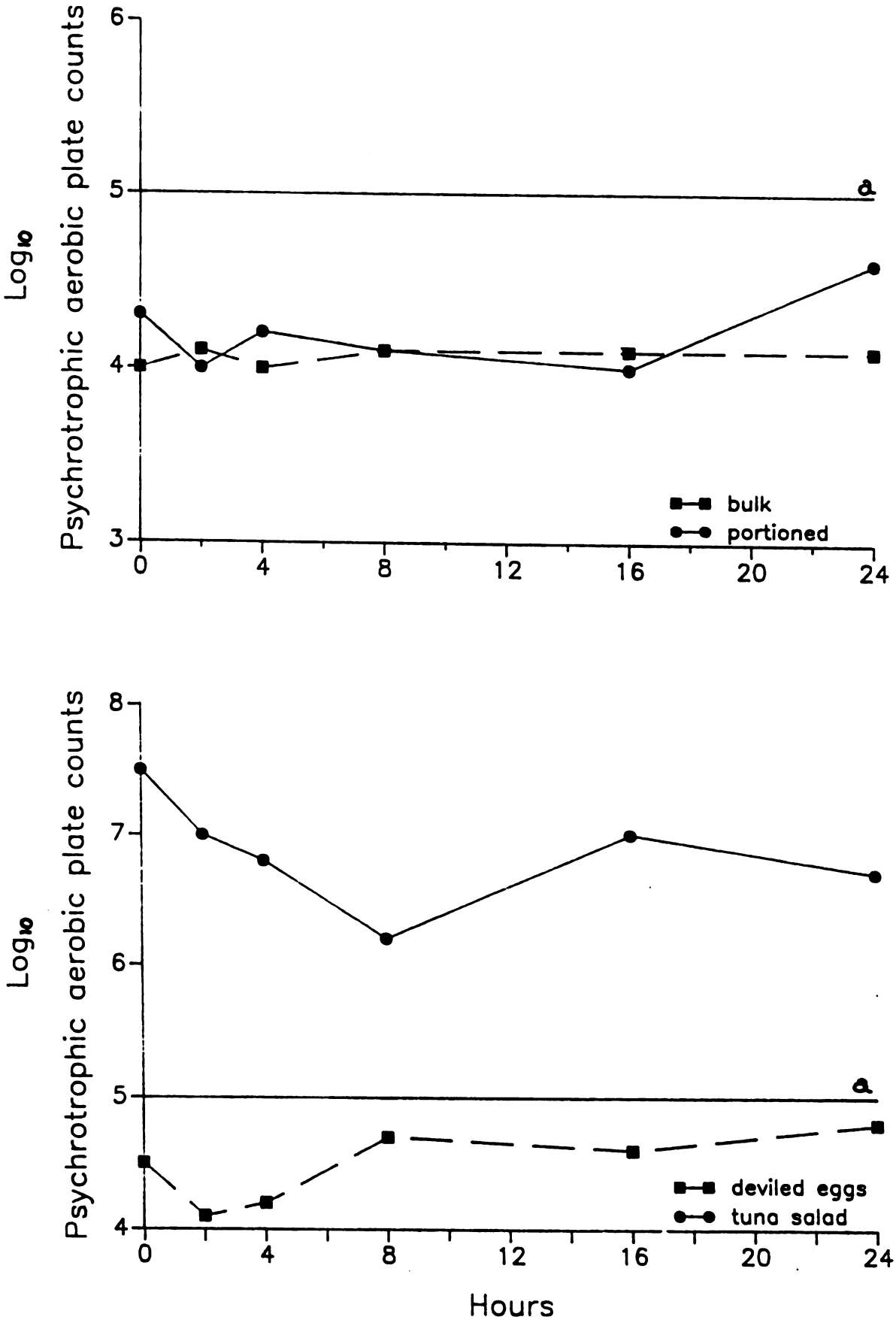
Experimental Product and Weight	Hours					
	0	2	4	8	16	24
	Mean $\log_{10}$ of CFU/g[b] + SD (SEM)					
Cottage cheese[c], 100 g	4.3 + 0.6 (0.3)[d]	4.0 + 0.0[e] (0.0)	4.2 + 0.3[f] (0.2)	4.1 + 0.2[e] (0.1)	4.0 ± 0.1[e] (0.04)	4.6 ± 1.1[f] (0.5)
Cottage cheese, bulk 1.2 kg	4.0 + 0.0 (0.0)	4.1 + 0.2 (0.1)	4.0 + 0.0 (0.0)	4.1 + 0.2 (0.2)	4.1 + 0.1 (0.04)	4.1 + 0.1 (0.04)
Tuna salad[c], 100 g	7.5 + 0.2 (0.1)	7.0 + 0.4 (0.2)	6.8 + 0.6 (0.3)	6.2 + 0.8[f] (0.4)	7.0 + 0.6 (0.3)	6.7 + 0.2 (0.2)
Deviled eggs[g], halves 100 ± 10 g	4.6 + 0.9[f] (0.4)	4.1 + 0.2[h] (0.2)	4.2 + 0.2[e] (0.2)	4.7 + 0.9 (0.4)	4.6 + 0.9 (0.4)	4.8 + 1.0 (0.4)

a N = 6, ± standard deviation; (standard error of the mean)
b CFU/g = colony forming unit per gram
c Portioned in a laboratory
d Standard error of the mean
e N = 4, ± standard deviation; (standard error of the mean)
f N = 5, ± standard deviation; (standard error of the mean)
g White and yolk salad
h N = 3, ± standard deviation; (standard error of the mean)

Figure 8a. Laboratory study: Mean of log psychrotrophic aerobic counts of bulk and portioned cottage cheese held on a cold-serving unit in a laboratory for 24 h.

Figure 8b. Laboratory study: Mean of log psychrotrophic aerobic counts of deviled eggs and portioned tuna salad held on a cold-serving unit in a laboratory for 24 h.

[a] 5 logs/g is the maximum psychrotrophic aerobic counts used for this study.


Log10 Psychrotrophic aerobic plate counts
6
5
4
3
a
bulk
portioned
0
4
8
12
16
20
24
Log10 Psychrotrophic aerobic plate counts
8
7
6
5
4
a
deviled eggs
tuna salad
0
4
8
12
16
20
24
Hours

differences in age of cottage cheese (Emmons, 1963), and laboratory error.

Table 16 presents linear correlation and regression analyses of psychrotrophic aerobic counts vs. time at ≥95% levels for four experimental products held on a cold-serving unit in a laboratory for 24 h. Portioned tuna salad showed a significant decrease ($r=-.68$; $p<0.001$). Bulk cottage cheese, portioned cottage cheese and deviled eggs showed a lack of significance (Table 16).

Psychrotrophic aerobic counts: Field

Seventy-six percent (76%) of 72 samples taken over 4 h had psychrotrophic aerobic counts $>10^5$ CFU/g (Hobbs and Gilbert, 1970; Fowler et al., 1973) (Appendix A, p. 1-8). One-hundred percent (100%) of samples of bulk cottage cheese and portioned tuna salad samples were not compliant; counts from portioned cottage cheese and deviled egg samples were $\geq 10^5$ CFU/g in 67% and 77% of situations, respectively.

Table 17 presents the mean $\log_{10}$ of psychrotrophic aerobic counts of four experimental products held on a cold-serving unit in three field sites for 4 h. Populations in portioned cottage cheese and tuna salad consistently increased from 0 to 4 h (Figures 9a and 9b). Mean $\log_{10}$ counts in bulk cottage cheese increased by 2 h to 6.0 ± 0.3 and decreased to 5.8 ± 0.1 at 4 h. Deviled eggs showed a similar inconsistency in growth (Figure 9b). Inconsistency was attributed to lack of control in product preparation, possible differences in food composition among batches, differences in age of cottage cheese (Emmons, 1963) and laboratory error.

Table 16. Laboratory study: Linear correlation and regression analyses[a] of $\log_{10}$ psychrotrophic aerobic plate counts vs. time for four products held on a cold-serving unit in a laboratory for 24 h.

Experimental Product	Number of samples	Regression equation	r	r^2	Level of significance
Cottage cheese, portioned	19	Y = 4.2 + -0.020(X)	-.15	.024	n.s.[a]
Cottage cheese, bulk	24	Y = 4.0 + 0.007(X)	.15	.023	n.s.
Tuna salad, portioned	23	Y = 7.5 + -0.161(X)	-.68	.468	p<0.001
Deviled eggs, halves	18	Y = 4.3 + 0.033(X)	.02	.024	n.s.

[a] Analyses was calculated to 8 h because data collected after 8 h was constant.

[b] n.s. = not significant

Table 17. Field Study: Mean[a] of $\log_{10}$ psychrotrophic aerobic plate counts taken from the surface center of four experimental products held chilled on a cold-serving unit in three field sites for 4 h.

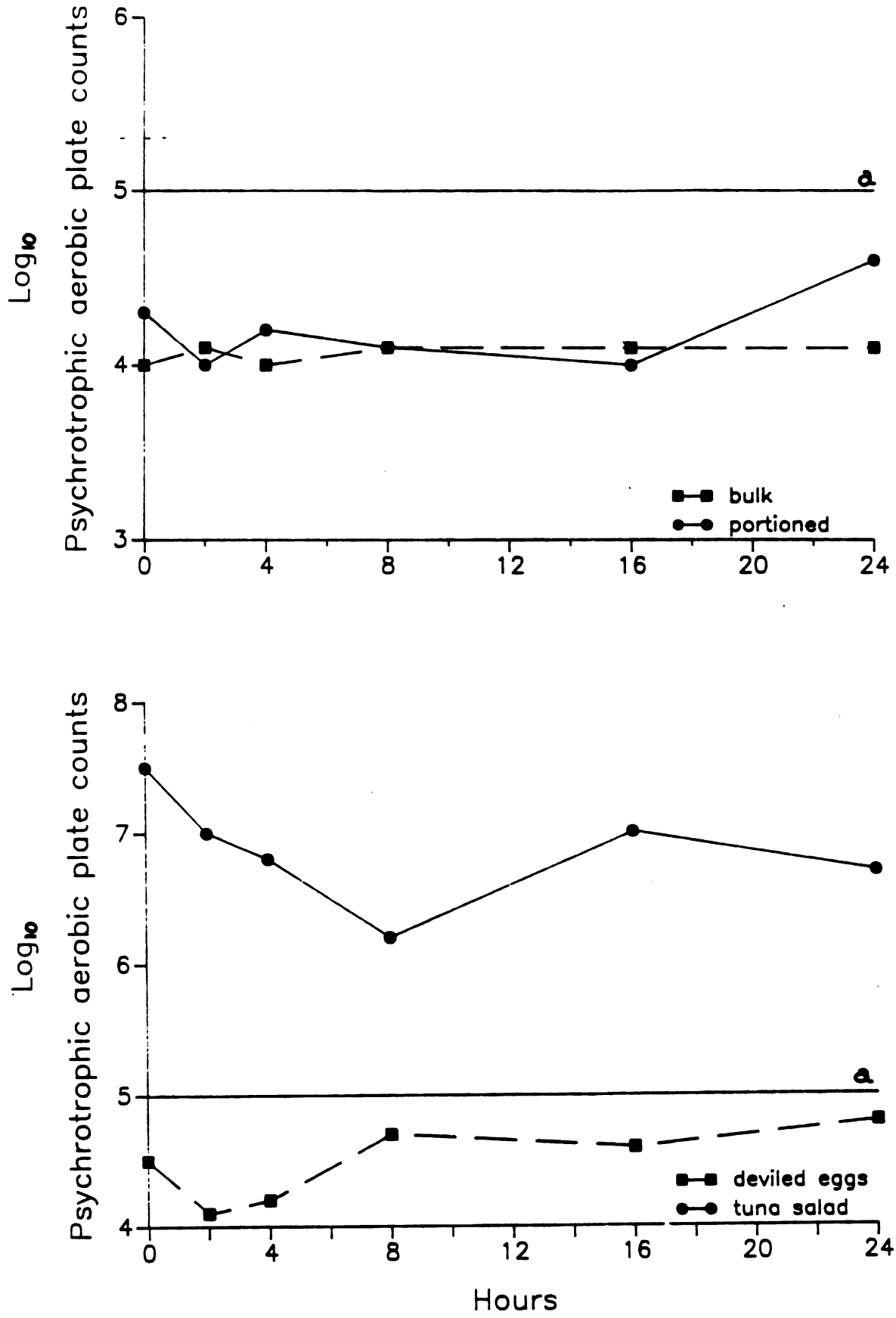
Experimental Product and Weight	Hours		
	0	2	4
	- - Mean $\log_{10}$ of CFU/g[b] ± SD (SEM)- -		
Cottage cheese[c], 100 g	5.2 ± 1.0 (0.4)	5.5 ± 1.2 (0.5)	5.7 ± 1.3 (0.5)
Cottage cheese, bulk 1.2 kg	5.9 ± 0.1 (0.04)	6.0 ± 0.3 (0.1)	5.8 ± 0.1[h] (0.04)
Tuna salad[c], 100 g	6.5 ± 0.2 (0.1)	6.7 ± 0.2 (0.1)	6.7 ± 0.1 (0.04)
Deviled eggs[g], halves 100 ± 10 g	5.5 ± 1.1 (0.5)	4.9 + 1.0[e] (0.4)	5.5 ± 1.4[f] (0.6)

[a] N = 6, ± standard deviation; (standard error of the mean)
[b] CFU/g = colony forming unit per gram
[c] Portioned in a laboratory
[d] Standard error of the mean
[e] N = 5; ± standard deviation; (standard error of the mean)
[f] N = 4; ± standard deviation; (standard error of the mean)
[g] White and yolk salad
[h] N = 2; ± standard deviation; (standard error of the mean)

Figure 9a. Field study: Mean of log psychrotrophic aerobic counts of bulk and portioned cottage cheese held on a cold-serving unit in three field sites for 4 h.

Figure 9b. Field study: Mean of log psychrotrophic aerobic counts of deviled eggs and portioned tuna salad held on a cold-serving unit in three field sites for 4 h.

[a] 5 logs/g is the maximum psychrotrophic aerobic counts used for this study.


Log10 Psychrotrophic aerobic plate counts
6
5
4
3
a
bulk
portioned
0
4
8
12
16
20
24
Log10 Psychrotrophic aerobic plate counts
8
7
6
5
4
a
deviled eggs
tuna salad
0
4
8
12
16
20
24
Hours

Linear correlation and regression analyses of psychrotrophic aerobic counts vs. time at ≥95% level of four experimental products in three field sites is summarized in Table 18. None of the products showed a significant increase in psychrotrophic populations in field sites.

Psychrotrophic aerobic counts vs. product temperature: Laboratory and Field

Tables 19 and 20 present linear correlation and regression analyses of psychrotrophic aerobic counts vs. product temperature at ≥95% level for four products held on a cold-serving unit in a laboratory and three field sites. The results showed no signficance for any of the four products in the laboratory (Table 19). However, in field sites (Table 20) psychrotrophic populations in portioned tuna salad significantly decreased as product temperature increased ($r=-.49$; $p<0.05$); portioned cottage cheese, bulk cottage cheese, and deviled eggs showed no significance.

Cross product comparison between bulk cottage cheese and portioned cottage cheese: Laboratory and Field

Table 21 presents tests of significant mean differences between bulk and portioned cottage held on a cold-serving unit in a laboratory and three field sites. Mesophilic and psychrotrophic aerobic counts showed no significant difference ($t=-.62$ and $t=1.27$, respectively) in laboratory or field sites ($t=1.63$ and $t=.96$, respectively). However, due to variance in cooling media used in laboratory and field sites, product temperature was significantly different between bulk and pre-

Table 18. Field study: Linear correlation and regression analyses of $\log_{10}$ psychrotrophic aerobic plate counts vs. time for four products held on a cold-serving unit in three field sites for 4 h.

Experimental Product	Number of samples	Regression equation	r	r^2	Level of significance
Cottage cheese, portioned	18	Y = 5.2 + 0.111(X)	.17	.029	n.s.[a]
Cottage cheese, bulk	14	Y = 5.9 + 0.008(X)	.05	.004	n.s.
Tuna salad, portioned	18	Y = 6.5 + 0.035(X)	.39	.150	n.s.
Deviled eggs, halves	15	Y = 5.4 +—0.010(X)	-.02	.0002	n.s.

[a] n.s. = not significant

Table 19. Laboratory study: Linear correlation and regression analyses[a] of $\log_{10}$ psychrotrophic aerobic plate counts vs. product temperature for four products held on a cold-serving unit in a laboratory for 24 h.

Experimental Product	Number of samples	Regression equation	r	r^2	Level of significance
Cottage cheese, portioned	19	Y = 4.3 + -.012(X)	-.06	.003	n.s.[b]
Cottage cheese, bulk	24	Y = 4.0 + .010(X)	.24	.058	n.s.
Tuna salad, portioned	23	Y = 7.1 + -.022(X)	-.09	.007	n.s.
Deviled eggs, halves	18	Y = 4.6 + -.015(X)	-.05	.002	n.s.

[a] Analyses was calculated to 8 h because data collected after 8 h was constant.

[b] n.s. = not significant

Table 20. Field study: Linear correlation and regression analyses of $\log_{10}$ psychrotrophic aerobic plate counts vs. product temperature for four products held on a cold-serving unit in three field sites for 4 h.

Experimental Product	Number of samples	Regression equation	r	r^2	Level of significance
Cottage cheese, portioned	18	Y = 5.7 + -.045(X)	-.10	.011	n.s.[a]
Cottage cheese, bulk	14	Y = 5.8 + .016(X)	.20	.039	n.s.
Tuna salad, portioned	18	Y = 6.8 + -.026(X)	-.49	.240	$p<0.05$
Deviled eggs, halves	15	Y = 4.7 + .071(X)	.19	.035	n.s.

[a] n.s. = not significant

Table 21. Tests of significant mean differences of portioned and bulk cottage cheese in a laboratory and three field sites.

Site	t value	Level of significance
I. Laboratory		
Mesophilic aerobic counts	-.62	n.s.[a]
Psychrotrophic aerobic counts	1.27	n.s.
Product temperature	-2.27	$p < 0.05$
II. Field Sites		
Mesophilic aerobic counts	1.63	n.s.
Psychrotrophic aerobic counts	.96	n.s.
Product temperature	-3.10	$p < 0.01$

[a] n.s. = not significant

portioned cottage cheese in both the laboratory ($t=-2.27$, $p<0.05$) and field sites ($t=-30.10$, $p<0.01$). Temperature, however, was not high enough to affect bacterial populations.

Chapter V

DISCUSSION

Product temperature

Foods held at >7.2°C for >2 h can result in growth of foodborne pathogens during refrigerated storage (USDHEW, 1978; DHSS, 1980). Thus, temperature guidelines of >7.2°C (U.S.) were used in this study to evaluate CHSS since no guidelines for CHSS were available in the literature.

Temperature compliance. In the laboratory 75% (N=144) of temperature measurements of four experimental products held on cold-serving units were >7.2°C (USDHEW, 1978); in field sites 46% (N=72) of measurements were >7.2°C (Appendix A, p. 1-8). Similar results were reported in two studies monitoring temperatures of foods held chilled for display. Silverman et al. (1975) showed in two sets of temperature measurements: 60 and 75% were >12.8°C (temperature guideline used by Natick Research Laboratories). O'Brien et al. (1984) reported 47% of meat and fish salad samples were >12.8°C.

When product temperatures in the present study were compared to U.K. temperature guidelines (DHSS, 1980) for foods held during refrigerated storage (3°C ± 2°C) only 8% in the laboratory and 22% in field sites were acceptable. Furthermore, in U.K. catering operations if product temperature is 5-10°C, the food must be eaten within 12 h.

Fifty-nine percent (59%) of samples in the laboratory and field sites were 5-10°C. U.K. guidelines also recommend disposing foods at >10°C; thus, 28% of samples in this study would require disposal.

Product temperature and equipment. The two studies monitoring temperature of foods held chilled for display did not identify the cooling medium used for CHSS (Silverman et al., 1975; O'Brien et al., 1984). This study, used two cooling media. In the laboratory ice and mechanical cooling were used; in field sites, only mechanical cooling was used. Differences noted in product temperature in the laboratory and field sites were attributed to the differences in media and are discussed below.

In the laboratory ice placed on top of a mechanically cooled stainless steel basin was the medium used to maintain cold temperatures in food on the cold-serving unit. Ice could act as an insulator to the mechanically cooled basin. When ice in contact with a mechanically cooled surface is exposed to the environment, a higher temperature equilibrium in the food can result (ASRE, 1951). This higher temperature equilibrium could result in increased product temperatures.

Product temperature measurements in the laboratory were consistent with this principle. Three of four experimental products were <7.2°C at 0 h, but all product temperatures, including bulk cottage cheese, increased to >7.2°C by 2 h (Table 3; Figures 4a and 4b). Thus, ice in conjunction with mechanical cooling appears to increase product temperatures during CHSS.

In field sites the cold-serving unit used only a mechanically cooled stainless steel basin to maintain cold temperatures.

Placement of dishware directly onto the stainless steel basin can create a lower temperature equilibrium when compared to a similar cold-serving unit that uses ice placed on top of the mechanically cooled stainless steel basin. This practice could result in decreased product temperatures.

In field sites, all portioned products showed a decrease in product temperature to <7.2°C within 2 h (Table 6; Figures 5a and 5b). Furthermore, product temperature did not increase to >7.2°C by 4 h. Thus, the cold-serving units that only used mechanical cooling (i.e. in field sites) appeared to be more effective in maintaining food temperatures to ≤7.2°C.

Temperature of bulk cottage cheese increased by 2 h in both the laboratory and field sites (Tables 3 and 6; Figures 4a, 4b, 5a, and 5b). This was attributed to the plastic container (1 cm thick; 20 cm deep) which held the cottage cheese. Plastic like ice could have acted as an insulator. This provides a partial explanation for the increased product temperature of bulk cottage cheese. Other reasons were the dimensions of the container (20 cm by 12 cm) and the volume of cottage cheese (2.27 kg ± 0.1)

Product temperature and room temperature. In a laboratory bulk cottage cheese and portioned tuna salad showed a significant increase in product temperature as room temperature increased (Table 5). Product temperature was expected to increase as room temperature increased because food on a cold-serving unit is open to room temperature and humidity which may change depending on weather and use conditions (ASRE, 1951).

In the laboratory the temperature of portioned cottage cheese and deviled eggs did not significantly increase as room temperature increased (P $\geq$95%) (Table 5). The temperature of deviled eggs and portioned cottage cheese did not significantly increase as room temperature did probably because of different thermal properties.

In field sites only bulk cottage cheese showed a significant increase in product temperature as room temperature increased ($p<0.001$) (Table 8). Portioned products showed no significant change in product temperature as room temperature increased (Table 8).

The temperature of some products appeared to be more effected by room temperature than others. Therefore, it appears necessary to monitor temperature of foods held on a cold-serving unit at frequent intervals to identify potential hazards.

Microbiological growth patterns

At 0 h 100% of mesophilic samples in the laboratory and field sites were $>10^5$ CFU/g (Appendix A, p. 1-8). Samples at 0 h in 38% and 88% of situations in the laboratory and field sites, respectively, showed psychrotrophic populations $>10^5$ CFU/g (Appendix A, p. 1-8).

Mesophilic and psychrotrophic growth was observed for bulk and portioned cottage cheese and deviled eggs in the laboratory (Tables 9 and 15). However, all changes in microbiological populations were less than one log cycle in the laboratory. All experimental products in field sites (Tables 11 and 17) showed growth in mesophilic and psychtrophic populations. Except for psychrotrophic growth in portioned tuna salad held in the laboratory overall increases for all experimental products in the laboratory and field were less than one

log cycle. This indicates that growth is possible but slow during cold-holding for self-service.

Deviled eggs showed a significant decrease in mesophilic populations in the laboratory ($p<0.05$) (Table 10). However, the decrease was less than one log cycle probably because product temperature was too cold for rapid multiplication of mesophiles.

Microbiological growth during CHSS did not appear to present a problem under conditions of the study. However, 379 customers observed using the salad bars at 30 foodservice operations reportedly spilled foods, touched foods, placed head under the sneeze guard , and touched the wrong end of serving utensil. This direct customer access could lead to possible introduction of foodborne pathogens, especially *Staphylococcus aureus*, via food or serving utensils (Carsters and Sommer, 1985; Sommer, 1987).

Food composition also affects microbiological growth. Therefore, microbiological growth and its implications will be briefly discussed below for each experimental product.

Portioned cottage cheese. No significant increase in mesophilic populations over time in laboratory (24 h) and field sites (4 h) was reported ($P\geq 95\%$) (Tables 10 and 14). Overall growth was expected to be minimal because the composition of cottage cheese is usually 1.5-5% salt (which reduces a_w) and a pH of (<5.3) which helps inhibit and/or minimize bacterial growth (ICMSF, 1980).

Psychrotrophic populations were $>10^5$ CFU/g at 0 h in 33% of cottage cheese samples in a laboratory (Appendix A, p. 1) and 66% in the field sites (Appendix A, p. 2). High psychrotrophic populations such as 6-8 log10s/g at 0 h in cottage cheese could be attributed to

post-pasteurization contamination by equipment, water, air and personnel (Emmons, 1963; ICMSF, 1980) and/or storage temperatures $\geq 7.2^{o}C$ (Fowler et al., 1957). Since the code date was not reported for cottage cheese, it was not known if post-pasteurization contamination or age contributed to increased psychrotrophic populations.

No significant increase in psychrotrophic populations over time of portioned cottage cheese was reported in laboratory or field sites at ≥95% level (Tables 16 and 18). *Listeria monocytogenes* (Ryser, 1985), a pathogen, and *Pseudomonas* sp. (Marth, 1970), a psychrotrophic spoilage microorganism, have been shown to grow slowly in cottage cheese at temperatures $\leq 7.2^{o}C$ in other studies. Therefore, foodborne pathogens could possibly grow in portioned cottage cheese held on a cold-serving unit depending on such conditions as the initial number of organisms present and product temperature.

Bulk cottage cheese. No significant increase in mesophilic populations in bulk cottage cheese in laboratory or field sites was observed (Tables 10 and 12). Longree and White (1955) and Black and Lewis (1948) reported increased mesophilic populations occuring in white sauce and chicken salad held in bulk over time.

Psychrotrophic populations also did not significantly increase in bulk cottage cheese (Tables 16 and 18) in laboratory or field sites at ≥95% levels. However, Ryser et al. (1985) showed the survival of *L. monocytogenes* inoculated into 8 oz. cartons of cottage cheese stored at $3^{o}C$. This indicates that growth of pathogenic psychrotrophs may be possible in bulk cottage cheese during CHSS at temperatures $>7.2^{o}C$ over time.

Portioned tuna salad. One-hundred percent (100%) of portioned tuna salad samples showed mesophilic and psychrotrophic populations to be $>10^5$ CFU/g (Appendix A, p. 5-6). These high microbiological populations are also consistent with results reported in a study by Jopke and Riley (1968). These authors observed mesophilic plate counts of tuna salad samples (N=12) to be between $2.1x10^3$-$6.8x10^6$ CFU/g. Another study investigating microbiological populations of tuna salad showed only one sample (N=8) $\geq 10^6$ CFU/g; the remaining samples showed counts $\leq 10^4$ CFU/g (Fowler and Clarke, 1975). The pH was reported in Fowler and Clarke's study which could have minimized or inhibited reported bacterial growth. In the present study and in the study by Jopke and Riley, pH was not reported.

In the present study the tuna salad formulation included raw celery, which could have carried a broad spectrum of microorganisms in excess of 10^6 CFU/g (ICMSF, 1980). Processed vegetables usually show increased populations (Shapiro and Holden, 1960), most of which are harmless. Thus, raw celery in tuna salad probably increased mesophilic and psychrotrophic populations.

In laboratory and field sites no significant change in mesophilic populations was observed (Tables 10 and 12). Growth of psychrotrophic populations in laboratory was not significant (Tables 16), whereas in field sites no significant change was reported (Table 18). CHSS did not appear to cause the rapid proliferation of microorganisms because initial levels (0 h) of mesophiles and psychtrophs were high (Tables 9,11,15, and 17).

Because tuna salad formulations may include raw and/or processed vegetables, and the pH is not always known or monitored, additional

research is needed to determine: microbiological growth during CHSS of tuna salad and other processed meat salads that incorporate raw and/or processed vegetables at different levels of pH.

Deviled Eggs. One-hundred percent (100%) of deviled egg samples measuring mesophilic populations in laboratory and field sites, and 23% and 77% of psychrotrophic populations in laboratory and field sites, respectively were $>10^5$ CFU/g (Appendix A, p. 7-8). This is consistent with other investigations of microbiological populations in egg salad. Microbiological populations in egg salad were considered to be similar to deviled eggs since a) the main ingredients in both products are eggs and mayonnaise and b) both require processing which could lead to increased microbiological populations. In one study egg salad samples (N=8) showed bacterial populations ranging from 2.6×10^4-1.1×10^7 CFU/g (Jopke and Riley, 1968). Another reported 66% (N=9) of egg salad samples held chilled had mesophilic populations $>10^5$ CFU/g; three had counts $>10^6$ CFU/g (Pace, 1975). Fowler and Clark (1975) also showed counts $>10^6$ CFU/g in 2 of 3 samples of egg salad. No literature was available on psychrotrophic populations in egg salad or deviled eggs during CHSS.

Linear correlation and regression statistics show no significant increase ($p<0.05$) in mesophilic and/or psychrotrophic populations in laboratory or field sites (Tables 10,12,16 and 18). Thus post-processing contamination more likely contributed to populations $>10^5$ CFU/g rather than CHSS in deviled eggs. However, since food poisoning outbreaks involving *Salmonella* sp. are common in eggs and egg products, additional research on growth of *Salmonella* sp. in deviled eggs during CHSS would be beneficial.

Microbiological populations and product temperature

The effect of product temperature on microbiological populations was expected to be minimal because mesophilic and psychrotrophic growth at $\leq 15^{o}C$ is slow (Banwart, 1981). However, psychrotrophic populations in bulk cottage cheese significantly decreased ($p<0.05$) in the laboratory as product temperature increased (Table 20).

Microbiological Guidelines

This study and others have observed mesophilic populations $>10^5$ CFU/g in salads and salad items, this author questions using $<10^5$ CFU/g as a microbiologically safe guideline for all salads and salad items (Fowler et al., 1973; Hobbs and Gilbert, 1970). One-hundred percent (100%) of mesophilic counts in laboratory and field sites and 33 and 76% of pyschrotrophic counts in laboratory and field, respectively, in the present study could have been considered unsafe for consumption (Appendix A, p. 1-8).

The mesophilic counts of the four experimental products are consistent with other research investigating mesophilic populations of foods held chilled for display in retail outlets and foodservice operations. Christiansen and King (1971) showed 36% of salad and sandwich samples to have mesophilic populations $>10^6$ CFU/g. Another study reported mean aerobic counts to be: mixed green salad (1.6×10^7/g), green salad (1.9×10^7/g), and cole slaw (4.7×10^6/g) (Fowler and Foster, 1976). Thirty-six percent (36%) of sampled meat salads held chilled for service in a cafeteria setting showed mesophilic counts $>10^5$ CFU/g.

No established guidelines for psychrotrophic populations in salads and salad items were available. Furthermore, no literature investigating psychrotrophic populations in chilled salads or salad items was found. However, it was assumed that $\leq 10^5$ CFU/g (5 logs/g) was a feasible guideline because 10^6-10^8 CFU/g (6-8 logs/g) results in spoilage (ICSMF, 1980).

Current guidelines do not reflect differences in natural flora among products, separate guidelines may be needed for each menu group, i.e. salads, sandwiches, entrees, desserts, reheated vs. non-reheated foods (ICMSF, 1980). Therefore, these guidelines for mesophilic populations in salads and salad items may need to be re-evaluated. The guideline for psychrotrophic populations at 10^5 CFU/g appears to be feasible based on conditions in this study.

Bulk vs. portioned cottage cheese

Additional research is needed to establish guidelines on appropriate dimensions of food containers used during CHSS. Mean temperatures were significantly different (Table 21) between bulk and portioned cottage cheese. Thus holding foods in bulk on a cold-serving unit could be potentially hazardous because product temperatures may increase >7.2°C. No recommendation for specific food volume was determined for CHSS.

A t-test analysis showed no significant difference between mesophilic and psychrotrophic aerobic counts between bulk and portioned cottage cheese in laboratory or field sites (Table 21). According to the conditions of this study, mesophilic and psychrotrophic growth did not appear to be a potential hazard while

holding foods in bulk. However, under more abusive conditions, i.e. unsafe food handling practices prior to holding and temperatures >15°C during CHSS, foodborne pathogens could grow.

Chapter VI

CONCLUSIONS

Implications of the study for practice

This chapter will discuss the application of the principles of refrigerated storage to CHSS. The principles of refrigerated storage (refer to Chapter I) are: 1) refrigeration equipment must use mechanical cooling to temperatures $\leq 5^{o}C$ ($40^{o}F$) (USDHEW, 1978), 2) refrigeration equipment should operate at temperatures of $\leq 5^{o}C$ ($40^{o}F$) + $1.5^{o}C$ (oF) (NSF, 1980), and 3) internal temperatures of food items held in refrigeration equipment should be at $\leq 7.2^{o}C$ ($45^{o}F$) (USDHEW, 1978; NSF, 1980). These principles are applied to CHSS in the paragraphs below. Additional recommendations were also determined from this study and will also be discussed below.

Mechanical cooling should be the only method used for cold-serving units. Foods held on a cold-serving unit that uses ice in conjunction with mechanical cooling did not maintain product temperatures at $<7.2^{o}C$ ($45^{o}F$) for more than 2 h. Whereas, portioned foods held on a cold-serving unit that used only mechanical cooling showed product temperature $<7.2^{o}C$ ($45^{o}F$) after 2 h.

Since, room temperature can affect the temperature of products

held on a cold-serving unit, a thermometer accurate to $\pm 1.5^{o}C$ located in the warmest part of the mechanically cooled stainless steel basin should be installed for routine readings of the equipment. However, operating temperature was not determined in this study.

The temperature guideline of internal product temperatures of $\leq 7.2^{o}C$ ($45^{o}F$) is applicable to products held on a cold-serving unit during CHSS (USDHEW, 1978). Internal product temperatures at 2.5 cm (1 in) depths in the surface center (warmest part of the product) should be taken approximately every 30 min to identify a problem before it becomes hazardous.

In foodservice operations where ice and mechanical cooling are used to maintained temperatures $<7.2^{o}C$ ($45^{o}F$), Foods should not be held for ≥ 2 h to minimize/prevent microbiological growth. However, the length of holding for foods held on a cold-serving unit that uses only mechanical cooling to maintain temperatures $\leq 7.2^{o}C$ ($45^{o}F$) was not determined in the present study.

Cold-serving units should not be used to chill menu items. The purpose of a cold-serving unit is to maintain foods that have already been chilled to $\leq 7.2^{o}C$ ($45^{o}F$) in refrigeration or chilling equipment at internal temperatures of $\geq 7.2^{o}C$ ($45^{o}F$). Foods placed on a cold-serving unit at temperatures $>7.2^{o}C$ ($45^{o}F$) are at increased risk for microbiological growth.

Holding portioned potentially hazardous food items on a cold-serving unit is preferable to holding foods in bulk. Holding foods in containers ≥ 20 cm (8 in) deep on a cold-serving unit is not advisable. Food volume and container size were not determined in the present study.

Room temperature appeared to affect the temperature of the experimental products during CHSS. Therefore, product temperature should be monitored approximately every 30 min to identify a problem before it becomes a hazard.

Recommendations to foodservice operators.

Recommendations are applicable to cold-serving units of the type used in this study:

1. Foods held on a cold-serving unit should have internal temperatures of $\leq 7.2^{\circ}C$ ($45^{\circ}F$) at the surface center (the warmest part of the food).
2. Cold-serving units should only use mechanical cooling and not ice.
3. Foods held on a cold-serving unit that uses ice between the container of food and the mechanically cooled surface should be held ≤ 2 h.
4. Cold-serving units should not be used to chill potentially hazardous foods to $\leq 7.2^{\circ}C$ ($45^{\circ}F$)
5. Foods should not be held in containers ≥ 20 cm (8 in) depths.
6. Monitor product temperature approximately every 30 min.

Recommendations to foodservice equipment manufacturers

1. A thermometer located in the warmest part of the mechanically cooled stainless steel basin of the cold-serving unit and accurate to $1.5^{\circ}C$ should be installed to monitor equipment temperatures.
2. Temperature controls should be installed to enable operators to control equipment temperature. Temperature controls are necessary to compensate for fluctuations in environmental conditions, i.e.

room temperature and humidity.

Limitations of the study

A major limitation of the study was lack of control in experimental products. Samples of each experimental product during each replication should have been maintained at $\leq 7.2^{\circ}C$ ($45^{\circ}F$). This would have enabled the investigator to measure field time-temperature profiles with an ideal time-temperature profile. It would have also shown microbiological growth patterns under ideal temperature conditions.

Preparation of experimental products should have been performed in a laboratory instead of purchasing directly from one residence hall foodservice operation. This would have insured identical preparation methods by the same person being used for tuna salad and deviled eggs for each replication. The code date of cottage cheese should have been noted because as the code date nears the expiration date, there is more likely to be a greater microbiological population (Emmons, 1963).

The same cooling medium to maintain cold temperature should have been used. All laboratory work was performed prior to field samples and ice and mechanical cooling was used. However, at field sites, the space assigned on the cold-service unit was mechanically cooled. However, differences were beneficial to the study.

Furthermore, pH was not monitored for any of the products. Since low pH can inhibit microbiological growth (ICMSF, 1980), it is important to measure pH when sampling products. Application of these

recommendations possibly could have reduced variance in bacteriological data.

Recommendations for future research during CHSS

I. Microbiology

A. Determine microbiological growth in other experimental products

1. lettuce
2. meat salads
3. custard

B. Determine the effect of various levels of pH

1. Tuna salad at three pH levels
2. Potato salad at three pH levels

C. Determine the effect of a_w

D. Inoculation studies

1. *Listeria monocytogenes*
2. *Yersinia enterocolitica*
3. *Pseudomonas* sp.
4. *Staphylococcus aureus*

II. Practice of CHSS

A. Determine appropriate dimensions of containers

B. Determine length of holding time so guidelines can be established for Unicode

C. Determine the best materials for holding containers

1. Metal
2. China

D. Determine the effect of changing environmental conditions

E. Determine temperature gradients among equipment, products, and environment to develop predictable models upon which to base operating temperatures of equipment

III. Equipment

A. Compare other designs of cold-serving units

B. Determine equipment operating temperatures

C. **Determine the most effective place for thermometer to measure equipment temperature**

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APPENDIX A - Laboratory and Field Studies: Raw data for 216 samples of experimental products

Appendix A, p. 1 of 8

Replicate	Time (h)	Product x Location	Product Temperature (°C)	Room Temperature (°C)	Mesophilic Counts (CFU/g)	Psychrotrophic Counts (CFU/g)
1	0	11[a]	7.9	22.0	1700000	10000
1	0	11	9.0	22.0	1540000	10000
2	0	11	3.7	20.1	1810000	10000
2	0	11	3.5	20.1	2490000	10000
3	0	11	6.9	22.4	23800000	20000
3	0	11	7.0	22.4	14400000	415000
1	2	11	10.6	21.8	1060000	10000
1	2	11	9.7	21.8	1300000	10000
2	2	11	4.6	22.6	2580000	10000
2	2	11	4.8	22.6	2880000	10000
3	2	11	7.6	22.5	1700000	MV[b]
3	2	11	7.6	22.5	MV	MV
1	4	11	8.1	25.1	1070000	10000
1	4	11	8.9	25.1	1270000	10000
2	4	11	11.0	21.2	2620000	10000
2	4	11	8.3	21.2	3120000	20000
3	4	11	6.7	23.4	MV	MV
3	4	11	8.1	23.4	3420000	55000
1	8	11	11.6	25.6	10900000	10000
1	8	11	10.4	25.6	825000	10000
2	8	11	9.6	21.8	44000000	25000
2	8	11	7.6	21.8	1090000	10000
3	8	11	6.7	24.3	10300000	MV
3	8	11	7.9	24.3	26000000	MV
1	16	11	11.1	21.0	780000	10000
1	16	11	4.1	21.0	1030000	10000
2	16	11	6.0	23.0	5660000	15000
2	16	11	8.4	23.0	15300000	10000
3	16	11	7.2	23.7	6400000	MV
3	16	11	8.3	23.7	3200000	MV
1	24	11	10.2	22.4	410000	10000
1	24	11	10.9	22.4	680000	35000
2	24	11	7.1	22.1	2280000	10000
2	24	11	8.2	22.1	3760000	10000
3	24	11	8.9	24.3	13300000	MV
3	24	11	6.2	24.3	1390000	4110000

[a] pre-portioned cottage cheese in a laboratory

[b] MV = missing value

Appendix A, p. 2 of 8

Replicate	Time (h)	Product x Location	Product Temperature (°C)	Room Temperature (°C)	Mesophilic Counts (CFU/g)	Psychrotrophic Counts (CFU/g)
1	0	12[c]	5.2	20.8	14300000	10000
1	0	12	5.1	20.8	20350000	10000
2	0	12	10.2	20.3	3420000	208000
2	0	12	8.4	20.3	11700000	330000
3	0	12	10.9	20.2	MV	2910000
3	0	12	9.8	20.2	19600000	1110000
1	2	12	7.2	23.5	18400000	10000
1	2	12	7.7	23.5	14200000	10000
2	2	12	3.7	21.8	5690000	1310000
2	2	12	4.7	21.8	11700000	760000
3	2	12	5.2	23.0	MV	4400000
3	2	12	4.9	23.0	MV	1730000
1	4	12	6.9	23.6	14300000	10000
1	4	12	4.2	23.6	18700000	10000
2	4	12	2.7	22.5	6730000	3900000
2	4	12	2.1	22.5	8800000	2700000
3	4	12	7.5	23.5	MV	4560000
3	4	12	4.1	23.5	19200000	2390000

[c] pre-portioned cottage cheese at three field sites

Appendix A, p. 3 of 8

Replicate	Time (h)	Product x Location	Product Temperature (°C)	Room Temperature (°C)	Mesophilic Counts (CFU/g)	Psychrotrophic Counts (CFU/g)
1	0	21[d]	6.5	23.2	4150000	10000
1	0	21	6.0	23.2	4540000	10000
2	0	21	5.4	23.6	5750000	10000
2	0	21	4.6	23.6	4190000	10000
3	0	21	1.3	22.7	MV	10000
3	0	21	1.1	22.7	6550000	10000
1	2	21	9.7	23.0	4460000	10000
1	2	21	9.6	23.0	3450000	10000
2	2	21	5.7	23.7	925000	10000
2	2	21	6.8	23.7	3660000	10000
3	2	21	8.8	23.6	3630000	30000
3	2	21	6.5	23.6	1690000	10000
1	4	21	10.4	23.2	1650000	10000
1	4	21	11.2	23.2	3220000	10000
2	4	21	9.8	24.1	4120000	10000
2	4	21	8.7	24.1	925000	10000
3	4	21	7.5	23.5	4150000	10000
3	4	21	9.9	23.5	2880000	10000
1	8	21	11.5	25.1	2960000	10000
1	8	21	13.0	25.1	3000000	30000
2	8	21	8.9	23.9	3300000	10000
2	8	21	10.1	23.9	2770000	10000
3	8	21	13.0	23.9	MV	10000
3	8	21	13.6	23.9	30800000	10000
1	16	21	12.2	24.1	3450000	20000
1	16	21	13.5	24.1	3080000	10000
2	16	21	7.2	24.2	4030000	10000
2	16	21	8.6	24.2	4270000	10000
3	16	21	13.9	23.8	MV	10000
3	16	21	14.6	23.8	25300000	10000
1	24	21	12.5	23.1	645000	10000
1	24	21	12.9	23.1	4830000	20000
2	24	21	8.0	23.5	6140000	10000
2	24	21	8.4	23.5	3680000	10000
3	24	21	14.2	23.6	23900000	10000
3	24	21	14.8	23.6	22500000	10000

[d] Bulk cottage cheese at a laboratory

Appendix A, p. 4 of 8

Replicate	Time (h)	Product x Location	Product Temperature (°C)	Room Temperature (°C)	Mesophilic Counts (CFU/g)	Psychrotrophic Counts (CFU/g)
1	0	22[e]	6.4	21.0	5600000	725000
1	0	22	6.7	21.0	20400000	1100000
2	0	22	3.7	21.3	4120000	650000
2	0	22	4.8	21.3	3860000	690000
3	0	22	6.8	21.5	MV	810000
3	0	22	7.0	21.5	27200000	510000
1	2	22	9.5	23.9	7750000	605000
1	2	22	11.0	23.9	4210000	785000
2	2	22	7.2	22.4	6250000	550000
2	2	22	8.4	22.4	3120000	550000
3	2	22	9.8	25.3	21800000	1050000
3	2	22	10.5	25.3	13100000	4450000
1	4	22	12.2	24.6	7650000	805000
1	4	22	13.9	24.6	8200000	570000
2	4	22	8.6	26.5	2230000	MV
2	4	22	9.9	26.5	2680000	MV
3	4	22	12.1	24.6	MV	MV
3	4	22	11.3	24.6	MV	MV

[e] Bulk cottage cheese at three field sites

Appendix A, p. 5 of 8

Replicate	Time (h)	Product x Location	Product Temperature (°C)	Room Temperature (°C)	Mesophilic Counts (CFU/g)	Psychrotrophic Counts (CFU/g)
1	0	31[f]	6.5	22.7	130000000	28700000
1	0	31	7.8	22.7	43600000	24800000
2	0	31	13.3	24.4	300000000	77500000
2	0	31	12.9	24.4	MV	49000000
3	0	31	3.9	21.3	49800000	22300000
3	0	31	4.8	21.3	98500000	30500000
1	2	31	9.8	23.0	18700000	1950000
1	2	31	10.5	23.0	226000000	22300000
2	2	31	11.2	21.0	241000000	11300000
2	2	31	12.4	21.0	28200000	39000000
3	2	31	5.4	22.4	82500000	9400000
3	2	31	7.0	22.4	114000000	10700000
1	4	31	10.6	23.0	134000000	51000000
1	4	31	11.0	23.0	MV	7500000
2	4	31	10.7	23.7	67800000	550000
2	4	31	11.1	23.7	132000000	4350000
3	4	31	7.2	22.5	38300000	6700000
3	4	31	8.0	22.5	89500000	5450000
1	8	31	10.7	22.9	MV	5050000
1	8	31	11.5	22.9	MV	MV
2	8	31	10.9	24.3	53600000	250000
2	8	31	13.5	24.3	75200000	6000000
3	8	31	10.0	23.6	65500000	260000
3	8	31	8.9	23.6	140000000	7000000
1	16	31	10.9	22.8	MV	20200000
1	16	31	7.6	22.8	57000000	130000000
2	16	31	10.2	23.9	30700000	4300000
2	16	31	12.0	23.9	73600000	8600000
3	16	31	8.9	23.4	37500000	3000000
3	16	31	7.4	23.4	23800000	5100000
1	24	31	12.4	23.4	34000000	9000000
1	24	31	11.0	23.4	48000000	4650000
2	24	31	9.7	23.4	54500000	2400000
2	24	31	9.2	23.4	32600000	5850000
3	24	31	9.1	23.2	44200000	5400000
3	24	31	8.8	23.2	71000000	4000000

[f] Pre-portioned tuna salad in a laboratory

Appendix A, p. 6 of 8

Replicate	Time (h)	Product x Location	Product Temperature (°C)	Room Temperature (°C)	Mesophilic Counts (CFU/g)	Psychrotrophic Counts (CFU/g)
1	0	32[g]	14.9	21.3	28000000	2600000
1	0	32	13.5	21.3	19000000	3100000
2	0	32	6.7	22.3	38000000	3100000
2	0	32	9.8	22.3	26000000	4200000
3	0	32	8.9	22.8	46000000	2100000
3	0	32	9.2	22.8	95000000	5800000
1	2	32	6.4	21.4	20000000	2700000
1	2	32	8.5	21.4	42000000	3800000
2	2	32	5.7	22.7	38000000	7100000
2	2	32	5.4	22.7	50000000	4000000
3	2	32	7.0	21.8	37000000	5400000
3	2	32	6.2	21.8	51000000	6100000
1	4	32	5.0	22.2	61000000	4400000
1	4	32	7.9	22.2	11000000	3200000
2	4	32	4.9	21.9	42000000	6300000
2	4	32	4.8	21.9	51000000	5100000
3	4	32	5.1	22.5	47000000	3400000
3	4	32	5.7	22.5	45000000	5800000

[g] Pre-portioned tuna salad at three field sites

Appendix A, p. 7 of 8

Replicate	Time (h)	Product x Location	Product Temperature (°C)	Room Temperature (°C)	Mesophilic Counts (CFU/g)	Psychrotrophic Counts (CFU/g)
1	0	41[h]	5.8	24.3	14500000	20000
1	0	41	4.7	24.3	1360000	10000
2	0	41	5.7	22.1	13100000	10000
2	0	41	6.2	22.1	10400000	15000
3	0	41	8.7	22.6	32000000	MV
3	0	41	5.2	22.6	22200000	1670000
1	2	41	10.0	23.8	1350000	MV
1	2	41	10.6	23.8	775000	25000
2	2	41	7.9	23.6	67500000	10000
2	2	41	8.0	23.6	2750000	10000
3	2	41	8.8	22.9	MV	MV
3	2	41	9.2	22.9	MV	MV
1	4	41	12.5	23.5	685000	20000
1	4	41	11.2	23.5	4330000	10000
2	4	41	7.2	22.0	920000	10000
2	4	41	8.1	22.0	2240000	30000
3	4	41	6.9	23.2	MV	MV
3	4	41	8.2	23.2	MV	MV
1	8	41	9.6	25.6	110000	20000
1	8	41	10.2	25.6	730000	20000
2	8	41	7.6	24.6	830000	10000
2	8	41	8.0	24.6	3300000	10000
3	8	41	10.0	24.6	10700000	660000
3	8	41	7.9	24.6	MV	635000
1	16	41	10.8	24.5	700000	10000
1	16	41	7.5	24.5	365000	10000
2	16	41	9.5	23.1	6250000	10000
2	16	41	7.9	23.1	2290000	10000
3	16	41	9.9	24.2	MV	780000
3	16	41	7.8	24.2	MV	520000
1	24	41	9.7	22.9	7800000	15000
1	24	41	8.7	22.9	4700000	40000
2	24	41	11.6	23.0	1540000	10000
2	24	41	10.1	23.0	3500000	10000
3	24	41	8.9	23.4	MV	1400000
3	24	41	6.5	23.4	MV	1400000

[h] Deviled eggs in a laboratory

Appendix A, p. 8 of 8

Replicate	Time (h)	Product x Location	Product Temperature (°C)	Room Temperature (°C)	Mesophilic Counts (CFU/g)	Psychrotrophic Counts (CFU/g)
1	0	42[i]	11.0	23.9	MV	10000
1	0	42	12.4	23.9	MV	25000
2	0	42	12.4	21.6	MV	685000
2	0	42	13.2	21.6	5700000	520000
3	0	42	10.7	19.5	MV	3040000
3	0	42	6.7	19.5	MV	4900000
1	2	42	7.2	24.0	MV	15000
1	2	42	6.8	24.0	MV	10000
2	2	42	9.5	23.8	MV	117000
2	2	42	9.4	23.8	MV	1450000
3	2	42	3.3	22.7	MV	MV
3	2	42	2.0	22.7	MV	MV
1	4	42	4.4	24.2	29600000	10000
1	4	42	4.5	24.2	MV	10000
2	4	42	10.6	25.2	MV	2490000
2	4	42	9.0	25.2	MV	2220000
3	4	42	4.6	18.8	4420000	6700000
3	4	42	5.8	18.8	MV	MV

[i] Deviled eggs at three field sites

APPENDIX B - Letter from Betty Wernette, MSU Sanitarian

MICHIGAN STATE UNIVERSITY

DEPARTMENT OF PUBLIC SAFETY EAST LANSING • MICHIGAN • 48824-1219

July 17, 1987

Ms. Angela Fraser
334 Food Science
Campus

Dear Angela,

Thank you for your interesting presentation of July 14, 1987 at the Brody Hall Cafeteria. The recommendations you have made, for your thesis work, will help to reinforce sanitation concerns in our food service facilities on campus.

As you recall, last year when we met, I expressed concern over food handling equipment capabilities for maintaining proper food temperatures. There had been several instances during routine inspection where temperatures were found to be in the danger zone, while being held in hot or cold units. The results of your study show that there is a legitimate concern with temperatures of foods in these units, especially cold handling equipment.

Hopefully this will be the start of a long and fruitful relationship between our office and the Food Science Department. Once again thanks for a job well done.

Sincerely,

Betty L. Wernette, R.S.
University Sanitarian

BLW/ph