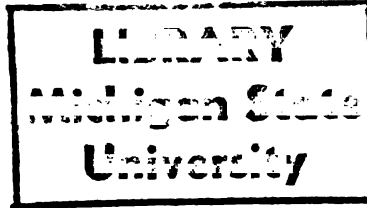




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IN MONITORING QUALITY OF REFRIGERATED SALADS
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USE OF A TIME-TEMPERATURE INDICATOR
IN MONITORING QUALITY OF REFRIGERATED SALADS

By

Louise Anne Campbell

A THESIS

Submitted to

Michigan State University

in partial fulfillment of the requirements

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ABSTRACT

USE OF A TIME-TEMPERATURE INDICATOR IN MONITORING QUALITY OF REFRIGERATED SALADS

By

Louise Anne Campbell

A time-temperature indicator was used for monitoring quality of refrigerated salads. The indicator was a pressure-sensitive label imprinted with a standard bar code (for product identification) and a color-changing time-temperature integrating polymer (TTIP). Bar code information was scanned and TTIP color measured as % Reflectance (% R) by a hand-held computer equipped with an optical wand.

In a control study, TTIP performance was evaluated at three constant temperatures, and reaction rates and activation energies were determined. TTIP color change followed first order kinetics. In the same study, salads were observed for quality parameters which were sensitive to thermal history. In a field study, salads labeled with indicators were traced through commercial distribution and retrieved at intervals during shelf life. Salad quality was determined by microbial, sensory, and color parameters and indicators were scanned and data recorded. No correlation between microbial quality and TTIP reflectance value was found. Sensory flavor scores were positively correlated with % R. Chlorophyll degradation of certain green vegetables in the salads was correlated with % R. Likely areas of thermal abuse in the distribution chain were identified.

TO BOB AND CAROL

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INTRODUCTION

I. BACKGROUND

A. THE TREND TOWARD REFRIGERATED FOODS

A few years ago, the refrigerated display cases in most grocery stores were stocked mainly with such standard items as dairy products and meat. Recent advances in food processing technology, coupled with consumer demand and ever-increasing competition among manufacturers to create new products and gain market share, have resulted in a proliferation of product offerings in refrigerated display cases. The deli section has been born and is growing rapidly. Dairy products - milk, cheeses, and yogurts - are increasing in number and variety. The meat section has expanded to include fresh fish and poultry. Refrigerated salads, sauces, and soups, as well as prepared sandwiches and entrees, are now available.

B. PROBLEMS ASSOCIATED WITH REFRIGERATED FOODS

The proliferation of refrigerated products has been accompanied by its share of problems. Refrigerated foods are complex systems, highly perishable, and subject to rapid deterioration if not stored and handled properly (Campbell et al., 1985). Except for a few products, such as fruits and vegetables, which reach maturity during

the distribution process, perishable foods continually lose some amount of quality from the time they leave the processor until they are consumed (Farquhar, 1982). Loss of quality may also be due to increases in microbial populations, changes in color or texture, separations in gels or emulsions, etc. A significant factor affecting rate of change of many of these quality parameters is temperature.

C. QUALITY LOSS

Food deterioration typically follows a zero order reaction (constant rate-of-loss) or a first order reaction (shelf life declines exponentially) (Labuza, 1979). In the case of perishable foods, the rate of quality loss usually increases with rising temperature, following the Arrhenius relationship (Labuza, 1980). Therefore, careful monitoring of time-temperature exposure of a product becomes an important element in estimating product quality and remaining shelf life.

D. ROTATION OF STOCK

Rotation of most refrigerated products is based on a First In, First Out (FIFO) system. Product packages are marked with a code date, which may be a "use by" or a "sell by" date. The basic flaw in this system is that products are rotated strictly on the basis of age, and storage temperature throughout handling is not considered. Jeffrey (1985) reported that a typical food product is handled and moved at least 17 times between harvest or manufacture and point of consumption. Certainly a great deal of variability in storage

temperatures is encountered in this handling. These variabilities, which can severely affect product quality and shelf life, are ignored by a rotation system which is based only on product age.

E. ABUSES DO OCCUR

In spite of efforts by the food industry to optimize conditions during handling and distribution, time and temperature abuses do occur (Farquhar, 1977; Jeffrey, 1985). Since most food products are packaged for retail sale, quality of a product may not be evident until time of consumption. There is a need for a system which accurately monitors time-temperature history of perishable foods and is compatible with existing inventory management information systems (Fields, 1985).

F. A POTENTIAL SOLUTION

A system which monitors a product's thermal history during storage and distribution without damaging product or package integrity could provide information to facilitate rotation on the basis of actual product quality. Such a system could offer significant benefits, including:

1. Improvement in consistency of product quality, thus contributing to brand loyalty and repeat sales.
2. Strengthening of the distribution chain by pinpointing areas of abuse.
3. Reduction in product loss due to spoilage.
4. Improved inventory management.

A number of systems have been devised to solve this problem. One system has been introduced by Allied Corporation of Morristown, NJ under the trade name "LifeLines Inventory Management System."¹ This system is proposed as a means of monitoring time-temperature history of perishable products at any point between time of manufacture and time of retail sale. It consists of three components: indicator labels, a hand-held computer for recording label information, and accompanying software. The label is imprinted with a standard bar code for product identification, and an indicator code. The indicator code contains a time-temperature integrating polymer (TTIP) which changes color as a function of time and temperature. A variety of polymers are available, which change color at different rates, and thus provide for a wide range of temperature environments.

II. OBJECTIVES

A. OVERALL

The overall goal of this study was to evaluate the performance of the indicator component of the "LifeLines" system in monitoring shelf life quality of a refrigerated food product, namely, delicatessen-type salads.

B. SPECIFIC

1. To evaluate performance of the time-temperature integrating polymer (TTIP) in monitoring thermal histories.

¹Reference to the trade names "LifeLines" or "LifeLines Inventory Management System" does not constitute endorsement by the author or Michigan State University.

- a. To determine thermal reaction rates of TTIPs at various refrigeration temperatures.
 - b. To determine activation energies of TTIPs at temperatures encountered in the distribution and sale of refrigerated salads.
2. To identify, in a controlled temperature storage study, quality parameters of refrigerated salads which are sensitive to thermal history and are significant in determining remaining product shelf life.
3. To measure changes in these salad quality parameters during commercial distribution and to correlate those with changes in color reflectance of the TTIP.
4. To demonstrate the use of the TTIP in identifying areas of thermal abuse in the commercial distribution channel.

LITERATURE REVIEW

I. PERISHABLE FOODS AND TODAY'S FOOD INDUSTRY

A. PERISHABLE FOODS DEFINED

Perishable foods are defined by Farquhar (1982) as

"...those products which must be stored under special, controlled temperature conditions from the time they are harvested, slaughtered, produced or processed until the time they are consumed, if a satisfactory degree of original quality is to be maintained. In modern technology, perishable products include fresh, chilled or refrigerated products which have been stored at temperatures slightly above freezing and those food products that must be kept below the freezing point."

B. THE NEED FOR MONITORING THERMAL HISTORY

By definition, quality of perishable foods is dependent upon proper temperature handling. The effect of time and temperature on frozen food quality is well known and has been the subject of investigation by a number of authors: Van Arsdel et al. (1969), Singh and Wang (1977), and Jul (1984). Recent trends in consumer demands for foods that are "fresh" and "natural" coupled with rising sales in this area have focused attention on quality and shelf life of refrigerated foods (Fields, 1985).

An A.C. Nielson study of consumer complaints (1983) in regard to grocery items cited lack of freshness as a major problem, especially

in regard to frozen and refrigerated items. Perishables constitute approximately 50% of grocery purchases (Farquhar, 1982) and therefore represent a key component of the food industry. In a recent presentation, Fields (1985) pointed out several new technologies impacting the food industry: aseptic processing, automated warehousing, use of bar codes and scanning devices, controlled atmosphere storage, and flexible packaging. He concluded that "...these changes and trends are bringing product shelf life and the need for better temperature management into sharp focus."

The occurrence of thermal abuse during handling of perishables is common and has been the subject of many studies (Sanderson-Walker, 1975, 1979; Farquhar, 1977, 1982; Jeffrey, 1985). Sanderson-Walker (1979) stated that "the monitoring of temperatures in the distribution chain has indicated a need to evolve improved protection to the product for better quality assurance." An unpublished report by the American Frozen Food Institute (Farquhar, 1977) confirmed the mishandling of frozen foods throughout the distribution chain, and that time-temperature exposures commonly exceeded recommended guidelines.

Commonly used stock rotation systems are based on product age and do not account for variations in temperature to which a product has been subjected (Fields, 1985). Consequently, these rotation methods may be inadequate in optimizing stock rotation based on product quality or remaining shelf life. There exists a need to more accurately monitor temperatures encountered in the distribution channel. The ideal monitoring program would act as "...an early warning system, where

product that has experienced some temperature abuse can be moved swiftly to retail with sufficient high quality life remaining" (Farquhar, 1982).

II. TIME-TEMPERATURE INDICATORS

A. DEFINITION

A time-temperature indicator is a device which may be affixed to the outside of a product package to provide evidence of the thermal history to which the product has been exposed (Campbell et al., 1985). Ideally, the indicator could serve as a monitoring or decision-making tool, aid in stock rotation, improve inventory management, reduce spoilage losses, and assist in insuring delivery of the optimum quality product to the consumer. To date, at least 60 such devices have been patented (Farquhar, 1982), but none are in widespread use.

B. DESIRED CHARACTERISTICS

Desirable attributes of the 'ideal' time-temperature indicator were listed by Renier (1962):

1. Easy to read by unskilled personnel.
2. Reasonably accurate.
3. Small in size in comparison to product.
4. Size and shape easy to use on or with package.
5. Infinite shelf life.
6. Easily activated.
7. Maintenance free.

8. Irreversible.
9. Self-powered.
10. Inexpensive.

More recently, in a discussion of the new technologies presently impacting the food industry, Fields (1985) added these requirements:

1. Employ objective measurements (so decisions made are consistent).
2. Compatibility with existing management information systems.
3. Immediately correlatable with product quality.

C. CATEGORIES OF INDICATORS

Farquhar (1982) described four 'systems' for monitoring food handling: spot temperature checks, time/temperature recorders, code or open dating, and time temperature indicators.

Schoen and Byrne (1972) examined 44 'defrost' indicators and classified them into six categories based on the type of information they provided. The authors emphasized the importance of recognizing the specific product characteristic an indicator is to measure and stated that "no one indicator...could possibly indicate a given level of quality for all products, since all products differ in their time/temperature tolerance."

Byrne (1976) classified time-temperature indicators into three categories:

1. 'Defrost indicators' - those which react in some way (e.g., a color change) when a preselected temperature is reached;

2. 'Time-Temperature Integrators' - those which react to a combination of time and temperature, coming to an endpoint (e.g., a 'final' color) at a preselected time-temperature combination, but do not give any indication of how far past the endpoint they may be;
3. 'Time-Temperature Integrator/Indicators' - those which may be activated at a preselected temperature and indicate change (usually by color) along a graduated scale; and are thought to show the most promise.

Byrne (1976) identified three important criteria when considering implementation of a time-temperature indicator:

1. Accuracy of reaction time to within 10% and temperature to within 1.1°C acceptable;
2. Shelf life may be limited - performance may diminish with storage time;
3. The user should be aware that the indicator responds to temperature in its immediate area, and so is a monitor of storage condition rather than of product temperature.

D. HISTORY

Several comprehensive reviews of time-temperature indicators have been published (Schoen and Byrne, 1972; Byrne, 1976; Kramer and Farquhar, 1976; Farquhar, 1977, 1982).

First Patent Issued

According to Kramer and Farquhar (1976), "the earliest indicator for which a patent was approved was that of Midgley (1933), which was

based on the distortion of an ice figure upon thawing." Since then, other indicators have been developed which have depended on the use of bacteria or enzymes which undergo a change in appearance with temperature change; liquid-filled capsules which rupture with freezing and thawing (Kramer and Farquhar, 1976).

First Practical Device

Credit for the first 'practical' time-temperature indicator offered (for use with frozen foods) is given to Minneapolis-Honeywell (Renier et al., 1962). This indicator was designed to meet the needs of the United States Army Quartermaster Corps in the shipment of frozen foods overseas. The device had a yellow time-temperature scale which retained its appearance if stored or shipped within the temperature range of 0°F to +125°F. Fracture of a vial activated the device with release of an electrolytic solution onto an absorbent paper scale, resulting in a color change from yellow to red. The irreversible color change proceeded at a rate dependent on the temperature of the device. Composition of the electrochemical solution could be altered for different absorption rates. This device is no longer available.

Device Contains Message

Hu (1971) reported on a time-temperature indicator designed to reveal a preprinted message. This indicator makes use of the rate of oxygen permeation through plastic film, which is a reaction dependent on time and temperature. A colored solution contained within the pouch 'hides' the message at the outset. During storage, oxygen

permeates the pouch and reacts with the solution, rendering the solution colorless and revealing the message. More than one pouch, containing solutions of different concentrations, could be used to reveal sequential messages such as 'USE NOW' or 'DISCARD'.

Disposable Indicator

A disposable device offered by Bio-Medical Sciences was described for use in gauging product shelf life (Anon., 1975). The device is a label which shows a color bar accompanied by a scale. The indicator is activated at the time of packaging and cumulative exposure to time and temperature results in irreversible color advance along the scale. The indicator is programmed for specific storage conditions, e.g., for a product with a shelf life of one year at 0°F, color advances one unit of the ten unit scale every 40 days. At a higher temperature, the color advances more quickly and reaches the 'expired' end of the scale in less days. This indicator is small, so it assumes the temperature of the food rapidly, and is flexible, so it can be attached to a package for easy reading and without disturbing product integrity.

Enzyme/Substrate Indicator

Function of the 'i-point' monitor, proposed for use with products which deteriorate as a result of enzymatic degradation, is described by Rose (1981): breakage of a seal between two pouches allows reaction between an enzyme and a substrate containing a pH indicator. As the substrate is consumed by the enzyme, the system changes from alkaline

to acidic, and change in pH is indicated by color change. Rate of reaction, as affected by temperature, is controlled by choice of substrates.

LifeLines Computerized System

Fields and Prusik (1983) described a computerized system for monitoring shelf life of temperature sensitive products. The system is composed of three key components: "LifeLines" indicators, a hand-held computer, and accompanying software. The indicator consists of bar code for product identification and a color-changing polymer. The polymer is composed of diacetylenes which change color as a function of time and temperature. Bar code and polymer color are 'read' via an optical wand and information is stored in the hand-held computer. The hand-held computer is designed to correlate measurements of the polymer color with predetermined time-temperature characteristics of the product and provide a readout of product quality. On a larger scale, this system could be used as a tool in inventory management.

E. PERFORMANCE EVALUATIONS

A number of devices have been evaluated for performance by Schoen and Byrne (1972), Arnold and Cook (1977), Mistry and Kosikowski (1983), and Wells and Singh (1985) and others.

Kramer and Farquhar (1976) evaluated performance of several commercially available indicators, which fit Categories 2 or 3 previously described. They concluded that the indicators behave with a sufficient level of precision, but that modifications in terms of

methods of activation, scaling, readout, and reliability are desirable.

A device evaluated by Arnold and Cook (1977) failed to meet the manufacturer's performance claims. The device functions by color change of a dye-impregnated paper strip. The color change takes place as ammonia gas diffuses over the paper strip. The gas is released upon breakage of a glass vial and is contained within an impermeable transparent plastic tube where it diffuses over the paper strip. The manufacturer's claim that color change would move at uniform speed over constant temperature was not met.

Wells and Singh (1985) examined performance of four different indicators for use in frozen food transport. The amount of manipulation required for activation of the indicators and hand work necessary for attachment were pointed out as the most serious limitations of their use.

III. QUALITY LOSS IN FOODS DURING STORAGE

The relationship between temperature and rate of quality loss in foods has been explored by many authors, including Desrosier and Desrosier (1977), Labuza (1979, 1982), and Saguy and Karel (1980). Desrosier and Desrosier state:

"As a rule of thumb, reducing the temperature of a stored food 10°C doubles the storage life. Increasing the temperature 10°C cuts the storage life in half. The temperature of a storage chamber is important in retaining the quality of foods as well as for extending the period of time during which that quality is maintained."

Labuza (1982) discussed modes of food quality deterioration such as rancidity, microbial growth, enzymatic reactions, and loss of color, flavor, and nutrients. Labuza (1979) indicated that deterioration of many foods can be treated as a zero or first order reaction. Rate of quality loss can thus be represented by the equation

$$\frac{dA}{dt} = -k(A)^n \quad (1)$$

where

$\frac{dA}{dt}$ = rate of degradation of A with time

A = quality factor

t = time

k = rate constant

n = reaction order (zero or one)

The Arrhenius equation is used to describe the influence of temperature on reaction rate (Labuza, 1979):

$$k = k'e^{-E_a/RT} \quad (2)$$

where

k' = rate constant at infinitely large T

E_a = activation energy

R = gas constant

T = absolute temperature

The Arrhenius relationship indicates that a plot of $\ln k$ vs the reciprocal of absolute temperature yields a straight line. The slope of the line is equal to the activation energy divided by the gas

constant (Labuza and Riboh, 1982). If reaction rate at several high temperatures is known, the reaction rate at lower temperatures can be predicted by extrapolation of the line. This relationship can be used to predict product shelf life.

IV. APPLICATION OF INDICATORS TO THE FOOD INDUSTRY

The use of time-temperature indicators to reflect quality of foods has been discussed (Schoen and Byrne, 1972; Kramer and Farquhar, 1976; Schubert, 1977; Mistry and Kosikowski, 1983). Schoen and Byrne (1972) caution that the first criteria for using indicators as monitors of quality is to define what is meant by quality and that indicator selection should be governed by choice of quality attribute.

Labuza (1980) applied simple kinetics (zero or first order) to mathematically model loss of food quality. The "LifeLines" indicator utilizes a color-changing polymer which approximates first order kinetics with an Arrhenius dependence on temperature over a wide temperature range. Because both the indicator and food deterioration obey similar time-temperature kinetics, it has been proposed that simple relationships can be established to adequately correlate indicator reading to product quality (Fields and Prusik, 1983).

EXPERIMENTAL DESIGN AND PROCEDURES

This study was carried out in two phases: a laboratory study, in which indicators and salads were evaluated under controlled conditions; and a field study, in which indicators and product were traced through a commercial distribution chain.

I. MATERIALS

A. INDICATORS

Time-temperature indicators were manufactured and supplied by Allied Corporation of Morristown, NJ. A diagram of the indicator is shown in Figure 1. The indicator is a pressure-sensitive label imprinted with a standard bar code symbology and a color-changing time-temperature integrating polymer (TTIP). The polymer is a diacetylene that gradually and irreversibly changes color in response to cumulative temperature exposure (Fields, 1985). The TTIP becomes 'activated' at above-freezing temperatures. A variety of polymers, which change color at different rates, were available from the manufacturer. Polymers are identified by a one or two digit 'Material Code,' which is part of the bar code symbology. The material code is also a means of identifying the rate at which the polymer changes color. In the laboratory study, polymers with Material Codes 57 and 61 were evaluated. In the field study, polymers with Material Codes 63 and 65 were used.

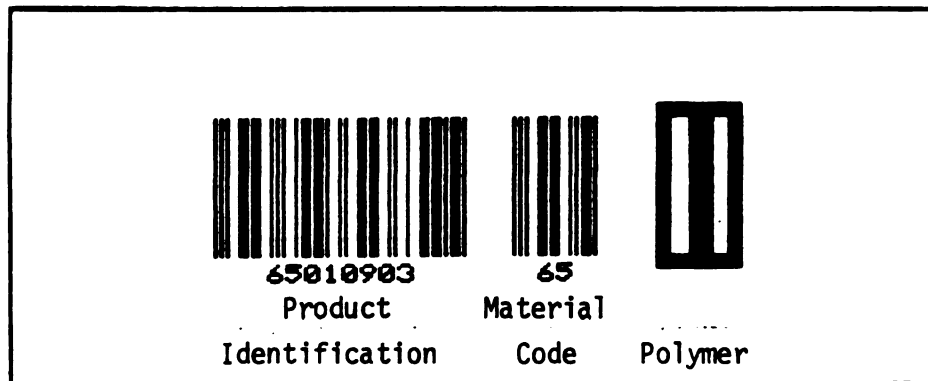


Figure 1. "LifeLines" Time-Temperature Indicator.

Table 1 lists four material codes used in this study and their reaction rates and activation energies as reported by the manufacturer (Friedman, 1985).

Table 1. Reaction rates of TTIPs stored at constant temperature.

Material Code	Reaction Rate (k') (day ⁻¹)	E_a (kcal/g mol)
57	1.668×10^{16}	22.6
61	1.234×10^{15}	20.7
63	3.538×10^{15}	21.4
65	2.535×10^{15}	21.4

B. THE "LIFELINES" SYSTEM

The time-temperature indicator evaluated in this study is part of a commercially available system for monitoring shelf life quality of perishable products. A diagram of the system components and pathways of information transfer is shown in Figure 2. The system is computer-based, and the TTIP is the system's sensor. The entire system consists of three elements: "LifeLines" indicator labels, a hand-held computer, and accompanying software.

The hand-held computer (the "HC-100") is equipped with an optical wand for scanning the bar code information and polymer color. Polymer color is measured by the wand as "% Reflectance." The computer uses

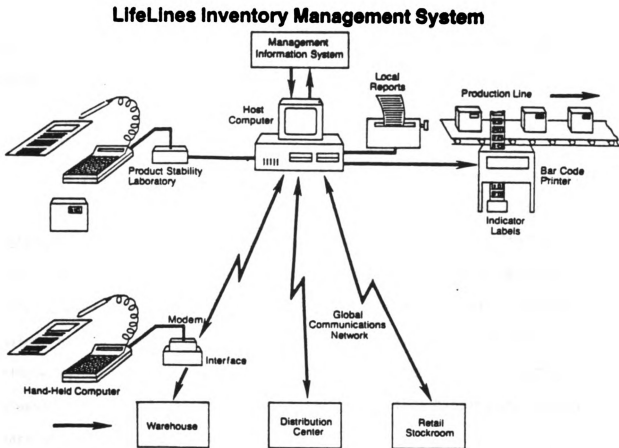


Figure 2. Schematic Diagram of "LifeLines" Inventory Management System.

software specifically developed for a given product to correlate indicator reading with predicted change in product quality. The HC-100, supplied by Allied, was used to scan and store information from the indicators. Each unit stores up to 3,000 indicator label readings in its memory before being downloaded to a host computer via telephone modem.

C. SALADS

Nine varieties of delicatessen-type salads manufactured and supplied by the Campbell Soup Company of Camden, NJ¹ were used in the study. Salads were of the following varieties: chicken, ham, fruit, Italian, slaw, vegetable, macaroni, potato, and seafood. Salads were marketed under the brand name "Fresh Chef" and are further described in Table 2. Salads had an expected shelf life of 23 days. They were packaged in single serving size plastic containers and then encased in a paperboard sleeve. Individual units were packed in corrugated shipping containers, each shipper holding six units.

Manufacture and packing of salads were handled by an independent manufacturer (under contract to Campbell Soup) at a location in Ft. Worth, TX. Retail distribution market of the salads was in the Denver, CO area.

¹References to the brand "Fresh Chef" or to the manufacturer, Campbell Soup Company, are not intended as endorsement of the product by the author or Michigan State University.

Table 2. Description of "Fresh Chef" salad varieties.

Salad Name	Code	Pkg. Size	Major Ingredients
Chicken with Almonds Salad	CSA	6 1/2 oz.	Cooked chicken meat, celery, mayonnaise, sweet peppers, almonds
Ham and Cheddar Cheese Salad	HCCS	6 1/2 oz.	Cooked ham, processed cheddar cheese, celery, sweet peppers, mayonnaise
Holiday Cole Slaw	HCS	12 oz.	Cabbage, carrots, celery, mayonnaise, red wine vinegar
Italian Pasta Salad	IPS	6 1/2 oz.	Macaroni, tomatoes, artichoke hearts, mushrooms, black olives, red wine vinegar, olive oil
Old Fashioned Potato Salad	OFPS	12 oz.	Potatoes, hard cooked eggs, mayonnaise
Seashell Macaroni Salad	SMS	14 oz.	Macaroni, green peppers, red peppers, salad dressing
Seafood Pasta Salad	SPS	6 1/2 oz	Macaroni, shrimp, crabmeat, hard cooked eggs, green peppers, celery, mayonnaise, sour dressing
Tropical Delight Fruit Salad	TDFS	6 1/2 oz.	Pineapples, grapes, oranges, coconut, cream, yogurt
Vegetable Garden Salad	VGS	6 1/2 oz.	Broccoli, cheddar cheese, cauliflower, mayonnaise, cider vinegar

II. LABORATORY STUDY

The primary objectives of the laboratory study were to determine effects of time, handling, and storage temperature on TTIP color change and to identify significant salad quality parameters.

A. INDICATORS

TTIPs of Material Codes 57 and 61 were evaluated to determine activation energies and reaction rate constants at each of three temperatures. Prior to application, indicators were stored at -30°C . Two indicators (one of each material code) were applied to each of 60 or more product packages. At least 20 of each were stored in each of three environmentally controlled cubicals maintained at constant dry bulb temperatures of 1.7 , 4.5 , and $7.2^{\circ}\text{C} \pm 1^{\circ}\text{C}$. At five time intervals over a 20-day period, bar codes and % Reflectance (color) of the TTIPs were measured by scanning with the optical wand. Scanning was repeated immediately five consecutive times for each indicator label reading.

B. SALADS

Fresh samples of salads were obtained from the manufacturing plant in Ft. Worth, TX and shipped by air to Michigan State University in East Lansing, MI. Upon receipt, salads were packed in corrugated shipping containers in the same manner as for retail distribution. Several samples of each salad variety were immediately stored in the same cubicals as the indicators. The remainder were stacked in three columns of 15 shippers each and wrapped (as a single unit) with stretch

wrap around the sides but not over the top. The wrapped stacks were subjected to vibrations to simulate normal truck transportation (Harte, 1985). Using an MTS electrohydraulic vibration table (Richmond, 1982), a frequency search of 3 to 100 Hz was conducted to determine resonance of the stack. The wrapped stack was vibrated at a frequency of 6.3 Hz, with a constant acceleration of 0.5 G, for a period of 15 minutes. Following vibration, at least 10 samples of each salad variety were placed in each of the 3 storage cubicals.

Quality of the vibrated salads was evaluated by subjectively noting and recording changes in physical condition (such as surface appearance, color change, separation and syneresis) and by plating for microbial count at five intervals over a 33 day period (10 days beyond expected shelf life). A typical data collection sheet for physical condition is shown in Appendix I. All physical evaluations were conducted by the same person, in the same room (227 Food Science), and under similar light. For microbiological evaluation, 25 gram samples were diluted 1:10 with 0.1% peptone broth and homogenized for one minute in a Stomacher Lab Blender. For total plate count, appropriate dilutions were cultured on Plate Count Agar (PCA, Difco, Detroit, MI) and incubated 35⁰C for 48 hours; psychrotrophic count was made on PCA, incubated at 7.2⁰C for one week; and yeast and mold count on Potato Dextrose Agar (PDA, Difco, Detroit, MI) acidified to pH 4.5 and incubated at 25⁰C for 48 hours (Pestka, 1985). All samples were prepared by the pour plate method.

III. FIELD STUDY

Major objectives of the field study were: to measure changes in salad quality during commercial distribution; to correlate those with changes in TTIP color reflectance; and to demonstrate use of the TTIP in identifying areas of thermal abuse in the distribution channel.

A flow chart of activity sequence for the field study is shown in Table 3.

A. SALAD MANUFACTURE

Of the nine varieties of salads, four or five varieties were manufactured and packed on Thursday of each week, and the remaining varieties on Friday. A typical manufacturing schedule is outlined in Table 4. Each variety was prepared and packaged separately, with processing machinery being cleaned between varieties. Packaged salads remained in the processing room (average temperature approximately 16.6°C) for various lengths of time (usually no more than six hours) before storage in a refrigerated warehouse. Temperature in the warehouse as observed by the author fluctuated as much as $\pm 4.1^{\circ}\text{C}$ about an average of 4.5°C . On Saturday morning, salads were shipped by refrigerated truck from the manufacturing plant and arrived at grocery store warehouses in the Denver, CO area on Monday morning. This study dealt only with salads distributed through the Safeway grocery chain. Average storage temperature on the trucks and at the Safeway warehouse was 1.7°C .

Table 3. Flow chart of field study activities.*

Activity	Salad Shelf Life Day
Apply indicator labels to sleeves; store in refrigerated warehouse	1-2 days before salad production
Apply indicator labels to shippers	Day 0
Pack salads in plastic containers; put sleeves on containers; scan 30-40 indicators	Day 0
Pack containers in shippers; scan 15-20 indicators	Day 0
Stack shippers on pallet	Day 0
Remove 'control' samples; ship directly to CIRT	
Truck picks up salads	Day 1, 2
Truck arrives at Safeway warehouse	Day 3, 4
Pick up salads at warehouse; scan indicators; ship to CIRT	Day 3, 4
Receive salads at CIRT; scan indicators; remove samples for quality analyses	Day 4, 5
Scan indicators; perform quality analyses (M, S, C)	Day 5, 6
Pick up salads at retail stores; scan indicators; ship to CIRT	Day 14, 15

Receive salads at CIRT; scan indicators; remove samples for quality analyses	Day 16, 17
Perform quality analyses (M, C)	Day 18
Perform quality analysis (S)	Day 22
Pick up salads at retail stores; scan indicators; ship to CIRT	Day 22, 23
Receive salads at CIRT; scan indicators; remove samples for quality analyses	Day 24
Perform quality analyses (M, C)	Day 25

*

Quality Analysis Codes: M=Microbiological; S=Sensory; C=Color

Table 4. Typical "Fresh Chef" salads manufacturing schedule.

Day	Time	Salad
Thursday	morning	Old Fashioned Potato Salad
		Seashell Macaroni Salad
	afternoon	Holiday Cole Slaw
		Italian Pasta Salad
		Vegetable Garden Salad
Friday	morning	Chicken with Almonds Salad
		Ham and Cheddar Cheese Salad
	afternoon	Seafood Pasta Salad
		Tropical Delight Fruit Salad

(Kirwin, 1985).

From each lot of salads produced, a 'control' group (labeled with indicators) was shipped by air directly from the manufacturing plant to research labs at Campbell Institute for Research and Technology (CIRT) in Camden, NJ. 'Control' salads and indicators were stored at optimum conditions (1.7°C) for at least their expected shelf life of 23 days. Control salads were used for comparisons in sensory and microbial analyses.

Salads were retrieved from the Safeway warehouse on the Monday morning following production, and from retail stores at various intervals throughout the expected shelf life. Indicators were scanned as soon as possible after salads were retrieved (usually within two hours). Salads were shipped overnight by air to research laboratories at CIRT for quality evaluations. Upon receipt, indicators were scanned and salads were removed for immediate quality analyses (microbiological, color). Some salads were held at 7.2°C (to simulate retail storage conditions) for quality analyses (sensory, color) which were conducted beyond expected shelf life.

B. INDICATOR APPLICATION AND SCANNING

Prior to application, indicators were stored at -30°C . For the field study, indicators were manually applied to product sleeves (secondary packages) and stored in a refrigerated warehouse for 24 to 48 hours. Sleeves were applied to primary containers immediately after manufacture of the salads. Indicators were applied to shippers at time of salad manufacture. Indicators on sleeves and shippers were

scanned at the time of salad manufacture (Day = 0) to obtain an initial reflectance value. For each salad variety, 30 to 40 sleeve indicators and 15 to 20 shipper indicators were each scanned three consecutive times. The numerical average of these three scans was computed as a MEAN SCAN. Mean scans for sleeves and shippers were recorded separately by salad variety. The average of mean scans on Day=0, for each variety/package is defined as the BASELINE. A partial list of BASELINES is shown in Table 5 with a complete list given in Appendix II.

Table 5. Baseline values for selected salads/packages.

Salad	Lot	Material Code	Package	Baseline
SPS*	1	63	shipper	78
SPS	1	63	sleeve	61
SPS	2	65	shipper	76
SPS	2	65	sleeve	72
SPS	3	65	shipper	78
SPS	3	65	sleeve	72

*Seafood Pasta Salad

C. QUALITY ASSESSMENTS

Determination of salad quality was based on microbial, sensory, and color evaluations. Analyses were performed on selected salads in each lot according to the scheme outlined in Table 6. Of salads

Table 6. Quality analysis schedule for field study.*

	Lot 1	Lot 2	Lot 3
Production date	(6/20-21)	(7/11-12)	(8/1-2)
Salad**			
Chicken	C S M	C	C
Ham	C S M	C	C
Fruit	C S M	X	C
Italian	C	C S M	C
Slaw	C	C S M	C
Vegetable	X	C S M	C
Potato	C	C	C S M
Macaroni	C	C	C S M
Seafood	C	C	C S M

*C = Color analysis; S = Sensory evaluation; M = Microbial counts;
 X = Not produced.

** Complete salad names given in Table 2.

produced on June 20-21, CSA, HCCS, and TDFS¹ were analyzed for sensory evaluation and microbial counts. All varieties produced were analyzed for color. Of salads produced on July 11-12, HCS, IPS, and VGS were subjected to sensory and microbial evaluation, and all for color. OFPS, SMS, and SPS produced on August 1-2 were analyzed for microbial count and sensory, and all salads for color.

Microbiological

Microbiological evaluations were performed on salads retrieved from the warehouse or retail stores on approximately Days 4, 14, and 23 from date of manufacture and on 'control' salads of the same age which had been shipped directly to CIRT and held at 1.7°C.

Thirty gram samples of each salad were diluted 1:10 and homogenized for approximately 1 minute with a Stomacher Lab Blender (Model 400). Table 7 lists counts, media, and incubation times and temperatures.

Sensory

Six of the salads (CSA, HCCS, TDFS, HCS, IPS, and VGS) were judged twice; the first time at about one week after production, and the second time just prior to the expiration date. The remaining three salads (OFPS, SMS, and SPS) were judged three times: one week after production, just prior to 'expiration', and 12 days after 'expiration'.

Retail samples and 'controls' (those samples held under optimum storage conditions) were evaluated by a panel of trained and experienced

¹All salad codes are listed in Table 2, p. 22.

Table 7. Types of microbial counts, media, and incubations.

Count	Medium	Incubation Temperature	Incubation time
Total aerobic	Plate count agar (D)	35°C	48 hrs
Coliform	Violet red bile + MUG* (D)	35°C	48 hrs
Lactobacillus	Lactobacillus MRS agar (D)	35°C**	48 hrs
Psychotrophic	Phytone Yeast Extract (D)	7°C	10 days
Yeast and mold	Trypticase Soy Agar (B)	25°C	72 hrs

(D) - Difco, Detroit, MI (B) - Baltimore Biological, Cockeysville, MD.

*4-methylumbelliferyl-B-d-glucuronide, 100 µg/ml VRB

**Incubated (anaerobic) in gas-pak jar or in CO₂ chamber, depending on availability.

taste testers for overall flavor quality. All sensory measurements were made using a nine point category scale in which 5.0 is set as the minimum score for flavor acceptability (Brusco, 1985).

Color

Degradation of chlorophyll content of broccoli, celery, and green pepper was determined by extraction of pigment and spectrophotometric analysis on a Lambda 5 spectrophotometer. The procedure, a modification of the AOAC (AOAC, 1985) procedure for chlorophyll extraction, is described in Appendix III (Fisher and Barr, 1985).

RESULTS AND DISCUSSION

I. LABORATORY STUDY

A. INDICATORS

The effect of time and storage temperature on TTIP color change were evaluated in a controlled temperature storage study.

Mean Reflectance Values of TTIPs

At least 20 indicators each of Material Codes (MC) 57 and 61 were placed on product packages and stored at each of three temperatures: 1.7, 4.5, and $7.2 \pm 1^{\circ}\text{C}$. Tables 8 and 9 list population sizes (n), mean reflectance values ($\bar{X}$), standard deviations (S.D.), and normalized reflectance values ($\text{adj}\bar{X}$) for each set of indicators at initial storage time (Day=0) and at five succeeding intervals. MEAN reflectance values for each set of indicators were obtained by averaging the mean values of five consecutive scans for each indicator in the set. The initial mean reflectance value for any set of indicators is called the BASELINE. Baselines for MC 57 stored at 1.7, 4.5, and 7.2°C were, respectively, 81, 81, and 79; and for MC 61 were 83, 84, and 82. Baselines were less than 100 due to loss of reflectance during shipping of indicators and holding time prior to initial scanning.

NORMALIZED reflectance values were used to standardize some comparisons between groups of indicators. Normalized values were

Table 8. Mean reflectance values observed for TTIP material code 57 during controlled temperature storage.*

Day	Temp ($^{\circ}\text{C}$)	n	$\bar{X}$	S.D.	adj $\bar{X}$
0	1.7	21	81	3.22	100
7	1.7	24	74	3.71	91
10	1.7	7	72	3.17	89
14	1.7	21	66	3.22	81
18	1.7	21	62	2.80	76
20	1.7	8	60	2.41	74
0	4.5	27	81	3.30	100
6	4.5	27	69	3.12	85
10	4.5	27	62	2.84	76
13	4.5	28	57	3.02	70
18	4.5	27	50	2.44	62
20	4.5	26	46	3.00	57
0	7.2	99	79	3.53	100
6	7.2	99	64	3.38	81
9	7.2	100	56	3.05	71
13	7.2	98	48	3.22	61
17	7.2	66	39	2.24	49
20	7.2	73	37	2.09	47

*Define n = number of samples scanned

$\bar{X}$ = mean reflectance values

S.D. = standard deviation

adj $\bar{X}$ = normalized reflectance values

Table 9. Mean reflectance values observed for TTIP material code 61 during controlled temperature storage.*

Day	Temp ($^{\circ}\text{C}$)	n	$\bar{X}$	S.D.	adj $\bar{X}$
0	1.7	21	83	2.24	100
7	1.7	24	66	2.38	80
10	1.7	7	61	1.28	73
14	1.7	21	54	1.76	65
18	1.7	21	47	1.46	57
20	1.7	8	44	1.64	53
0	4.5	27	84	3.91	100
6	4.5	27	60	2.17	71
10	4.5	27	50	1.14	59
13	4.5	28	41	1.90	49
18	4.5	27	31	1.73	37
20	4.5	26	28	1.61	33
0	7.2	99	82	2.83	100
6	7.2	99	52	2.88	63
9	7.2	100	41	2.01	50
13	7.2	98	30	1.70	36
17	7.2	66	20	1.94	24
20	7.2	73	18	1.76	22

* Define n = number of samples scanned
 $\bar{X}$ = mean reflectance values
 S.D. = standard deviation
 adj $\bar{X}$ = normalized reflectance values

obtained by dividing actual mean reflectance values by their baselines. Population sizes vary due to losses of some data during transfer between computer systems.

Reflectance values repeated for any individual TTIP are expected to be within 10 units, the difference due largely to light reflectance as measured by the optical wand (Prusik, 1985). Variability between TTIPs manufactured as one Material Code lot and stored until use may be reflected in the standard deviation (SD), as shown in Tables 8 and 9. For MC 57, over time and temperature, mean reflectance values ($\bar{X}$) ranged from 81 to 37 and SD ranged from approximately 2.1 to 3.7. For MC 61, over time and temperature, mean reflectance values ranged from 84 to 18, and the SD ranged from approximately 1.1 to 2.8 (with one exception; Day 0, 4.5°C).¹

In spite of the large range in mean reflectance values over time, standard deviations within each material code were not significantly affected by temperature. The mean of all standard deviations for MC 57 (n=18), across time and temperature was equal to 2.99, while the mean of all standard deviations for MC 61 (n=17) was 1.91. The difference between the mean SDs for the two material codes was significant at the 90% confidence level (Student T-Test). This implies that variance of MC 61 mean scans was significantly less than for MC 57. All indicators were scanned by the same person, and with the same wand.

¹The exception is in Day 0 reflectance values for MC 61 stored at 4.5°C. Investigation of raw data shows two of the indicators in this group (n=27) with unusually high mean reflectance values. The SD for this group was 3.91, and is considerably higher than the SDs for all other mean reflectance values for MC 61.

Increased variability in MC 57 is probably due to one or more of the following: difference in holding conditions prior to use, differences inherent to the polymer, or in the laminated coating over the polymer. Applying the principle that 95% of observed values of a normal population will lie within $\pm$ two SDs of the mean, the range of observed mean scans for MC 57 was approximately 12%, and 7.6% for MC 61.

The variance of mean scans for Material Codes 57 and 61 tested in the lab study was not affected by reflectance over the range of reflectance values (80 to 18) observed. Variance for MC 57 was observed to be significantly different from MC 61.

Individual Scans of Indicators

In the laboratory study, scanning was repeated five consecutive times for each indicator. Mean reflectance values were obtained by averaging the values of these five scans. Data were also analyzed to assess variability between individual reflectance values for the same indicator. This section addresses the results of variability of individual scans.

'Difference' is defined as the highest reflectance value of any indicator minus the lowest value for the same indicator, when scanned consecutively at any given time. For a given temperature, statistical analysis revealed that there was no significant correlation (90% confidence level) between the 'difference' of scans and the mean reflectances. Simply stated, the range of the five individual reflectance values for one indicator was not affected by the level of

reflectance, at the ranges encountered in this study. Therefore, data for all time intervals were pooled according to temperature and material code to determine if 'difference' was dependent on temperature and material code. Table 10 summarizes mean 'differences' and standard deviations for MC 57 and 61 at each storage temperature.

Table 10. Statistical summary of mean 'differences' of individual scans for two material codes stored at three constant temperatures.

Material Code	Storage Temperature					
	1.7°C		4.5°C		7.2°C	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
57	5.43	2.67	4.79	2.62	4.31	2.40
61	4.11	2.32	3.83	1.99	3.92	2.38

The average 'difference' for all temperatures for MC 57 is 4.84 vs 3.95 for MC 61. However, statistical analysis indicated that average 'differences' in Table 10 were not significantly correlated to temperature or to material code. Data in Table 10 indicates that 95% of individual scans for MC 57 ranged 8.6 to 10.8 reflectance units while those for MC 61 ranged 7.7 to 8.2. This compares favorably with Prusik (1985) who indicated that reflectance values for a single indicator, scanned consecutively at a given time, would be within ten units.

At the range of reflectance values encountered in this study (80 to 18 for MC 57 and 81 to 36 for MC 61), the expected range of reflectance values for consecutive scans of an individual indicator is fairly constant, at 7.7 to 10.8.

Reaction Rates and Activation Energies

Statistical summaries of mean reflectance values (actual and normalized) and standard deviations for MC 57 and 61 are provided in Tables 8 and 9. Normalized mean reflectance values for ALL individual indicators stored at each of three temperatures are plotted in Appendix IV, Figures a through f. Figures IVa, IVc, and IVe are plots of all data for MC 57 at 1.7, 4.5, and 7.2°C; and Figures IVb, IVd, and IVf for MC 61.

Averages of mean reflectance values were plotted on log coordinates (Y axis) vs. time (X axis). Figures 3, 4, and 5 are summaries of data in Figures IVa and IVb; IVc and IVd; and IVe and IVf; respectively. The two material codes clearly have two distinct reaction rates at a given temperature, as depicted by their different slopes in each graph. Comparison of the slope for MC 57 at the three different temperatures indicates a different reaction rate at each temperature; likewise for MC 61. The straight line relationships of log reflectance vs. time in Figures 3, 4, and 5 indicate a first-order reaction, with the slope of the line being proportional to the reaction rate at a given temperature. Linear regression analysis (SAS, 1976) was used to fit raw data (for a given temperature) of normalized reflectance values to the model form:

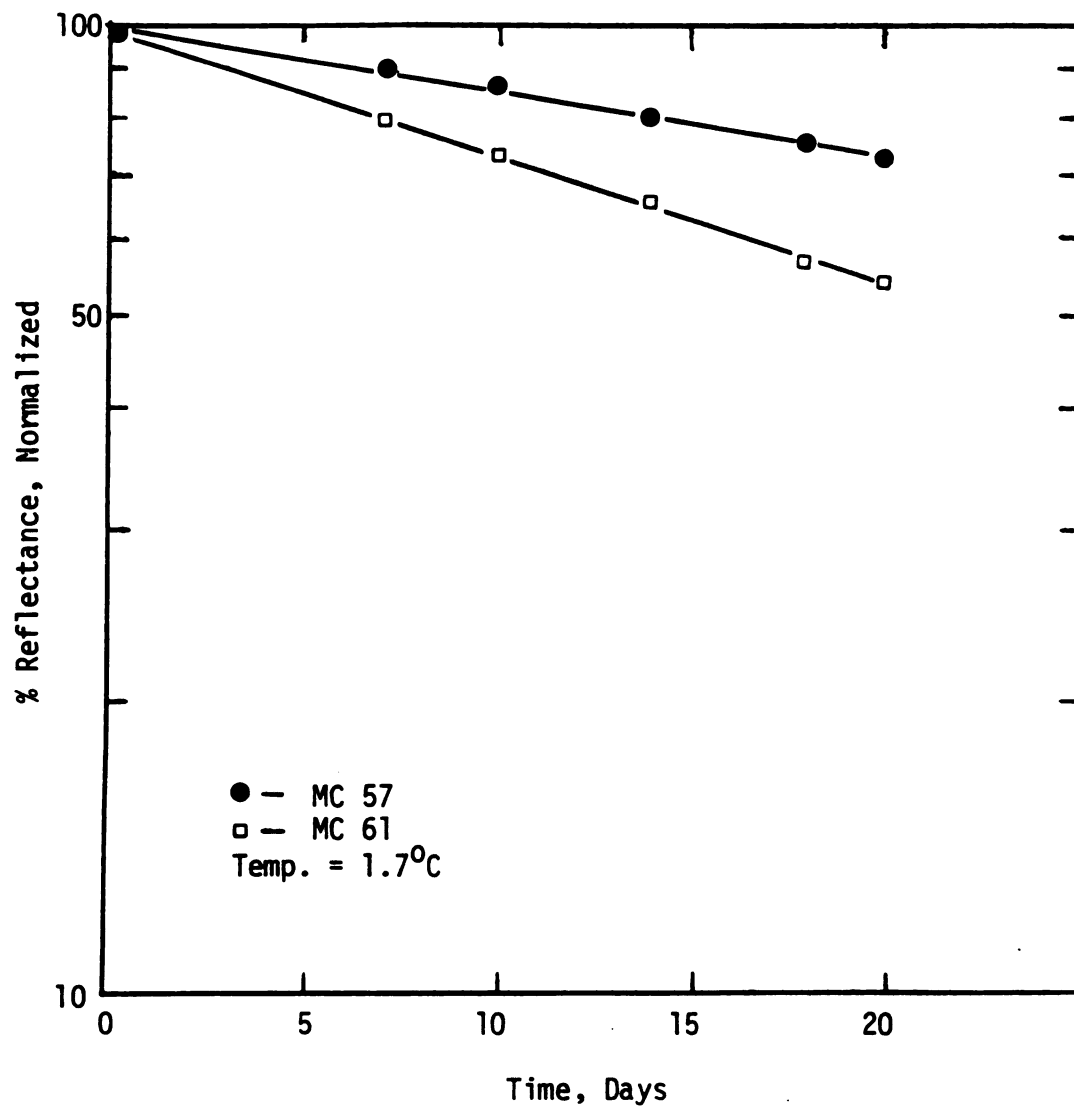


Figure 3. Summary of Normalized Reflectance vs. Time for Material Codes 57 and 61 at 1.7°C.

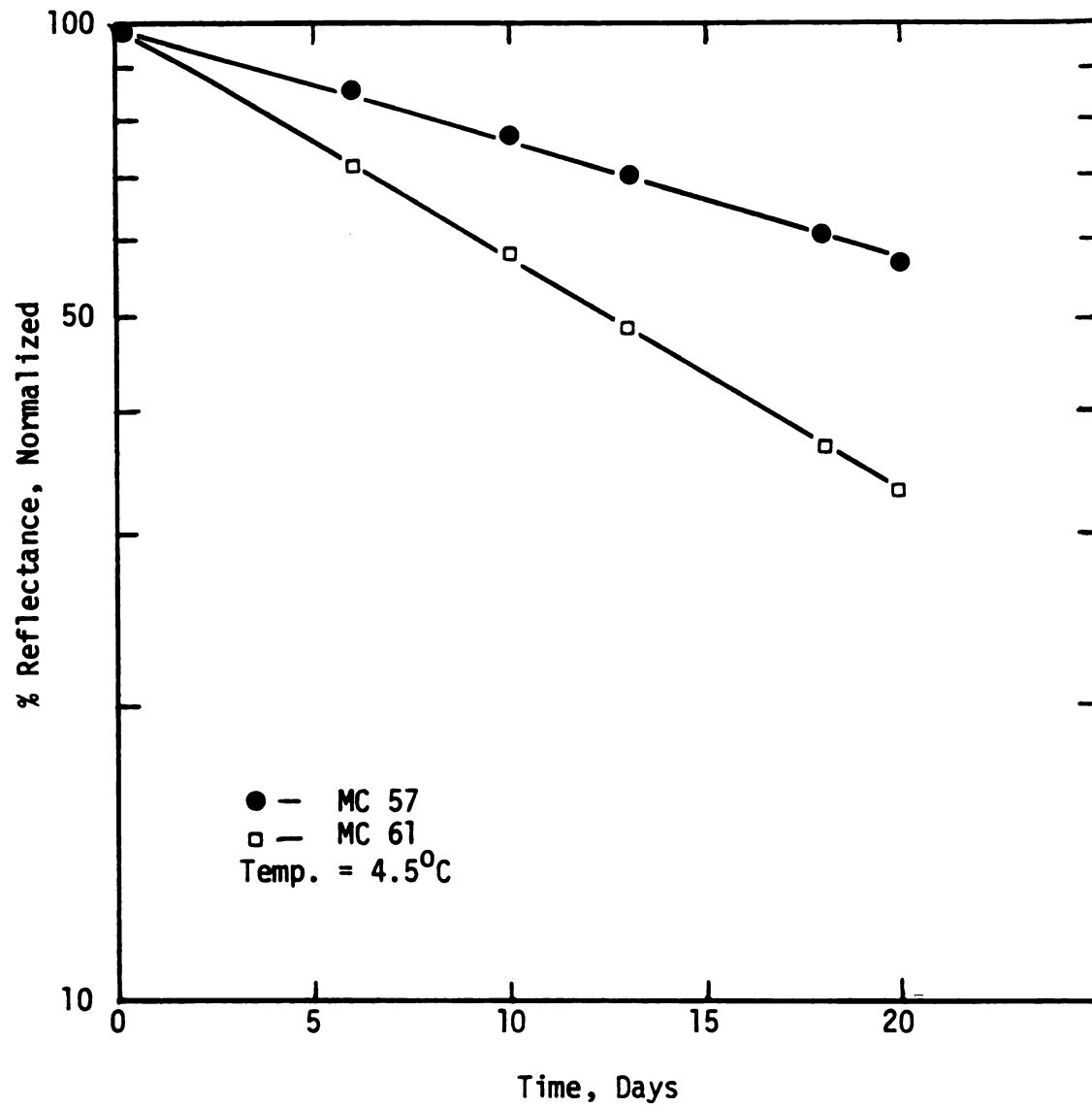


Figure 4. Summary of Normalized Reflectance vs. Time for Material Codes 57 and 61 at 4.5°C.

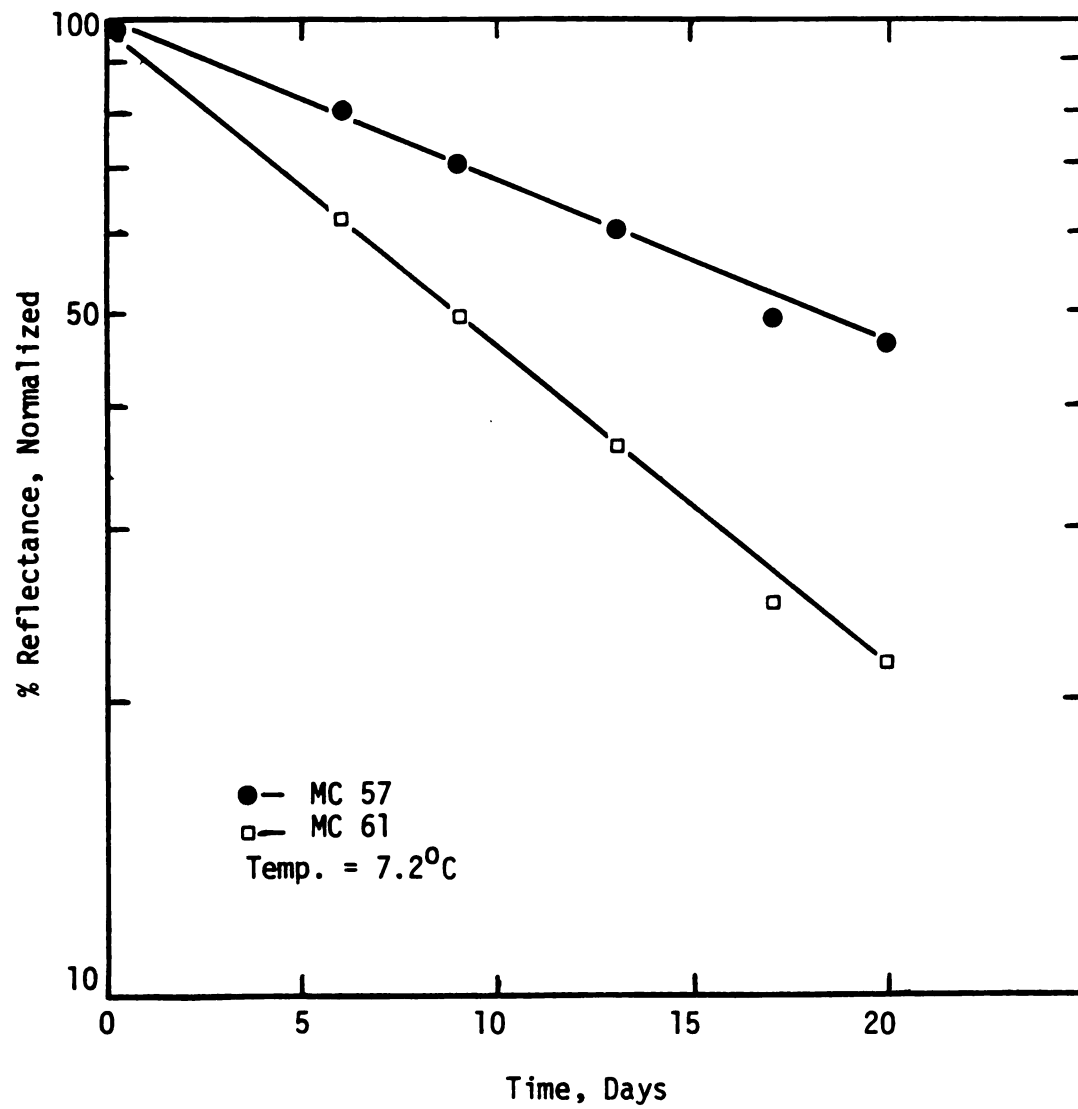


Figure 5. Summary of Normalized Reflectance vs. Time for Material Codes 57 and 61 at 7.2°C.

$$\ln (\text{adj}\bar{X}) = a + k (\text{time}) \quad (3)$$

where k = reaction rate constant for a given temperature and $\exp(a) = k'$, the rate constant at infinitely large T . Results for each material code and temperature are shown in Table 11.

Table 11. Calculated reaction rate constants (k) for two TTIP material codes at each of three constant temperatures.

Temp.	$1/T(K^{-1})$	MC 57		MC 61	
		$k(\text{day}^{-1})$	R^2	$k(\text{day}^{-1})$	R^2
1.7°C	0.003638	0.0154	0.844	0.0309	0.977
4.5°C	0.003602	0.0279	0.936	0.0554	0.985
7.2°C	0.003567	0.0404	0.952	0.0781	0.980

As revealed in Figures IVa through IVf, regression fits were quite good for both material codes at all temperatures, with R-squared exceeding 0.930, except for MC 57 at 1.7°C where R-squared = 0.844. All regression analyses were significant at the 0.001 level.

The activation energy for each material code was calculated using the Arrhenius relationship. A plot of $\log k$ vs. reciprocal of absolute temperature yielded a straight line, with slope being proportional to activation energy (E_a) divided by the gas constant (R). In Figure 6, reaction rates listed in Table 11 are plotted against reciprocals of absolute temperatures. Activation energies of MC 57 and 61 are quite

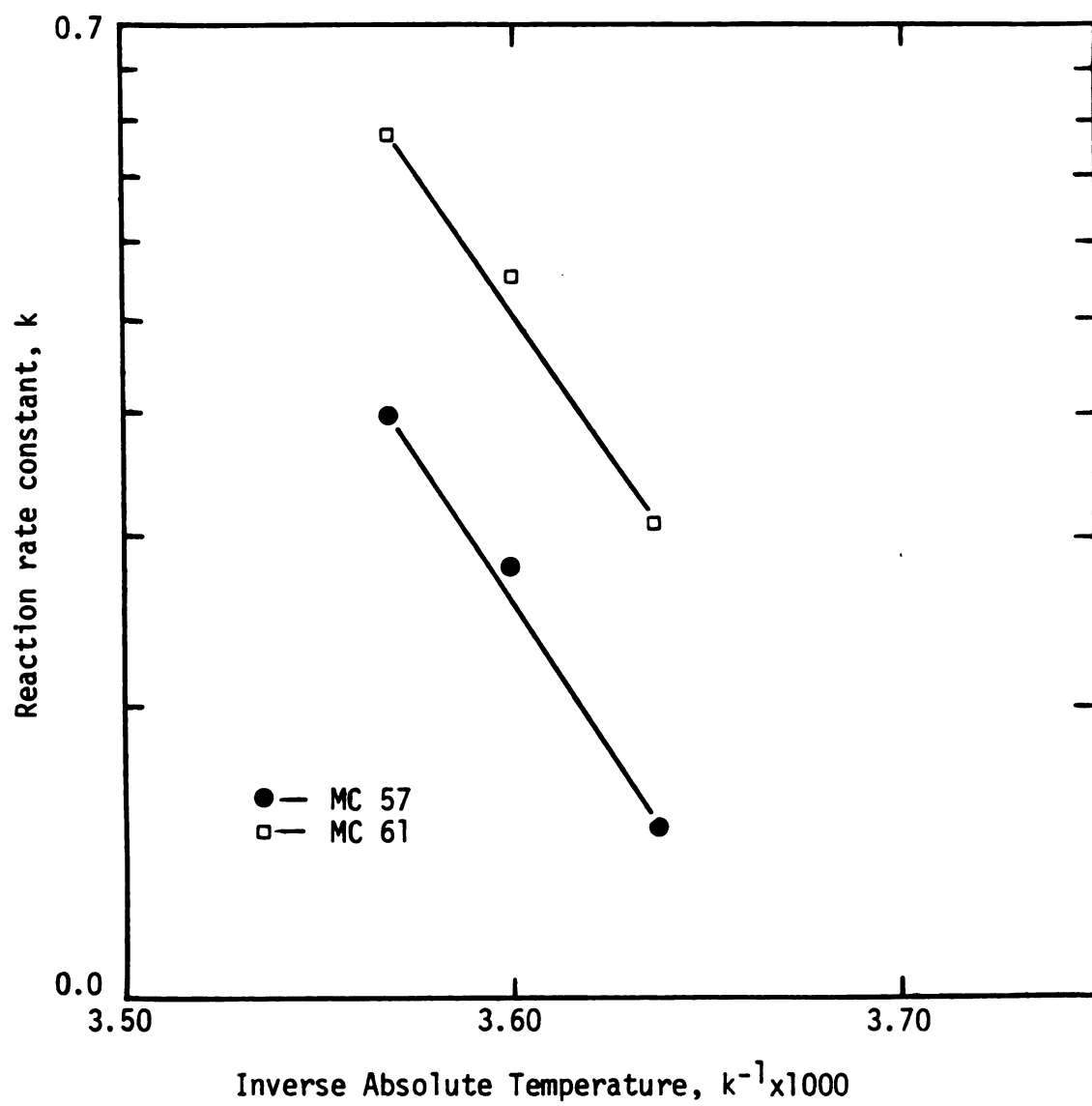


Figure 6. Plot of Reaction Rate Constants vs. Inverse Absolute Temperatures.

close, at 26.5 kcal/g mol and 25.5 kcal/g mol, respectively. Table 12 is a summary of kinetic parameters calculated in this study as compared to values reported by the manufacturer (Friedman, 1985).

Table 12. Comparison of kinetic parameters calculated in lab study and reported by manufacturer.

Material Code	$k' \text{ (day}^{-1}\text{)}$		$E_a \text{ (kcal/g mol)}$	
	Calculated	Reported	Calculated	Reported
57	2.104×10^{19}	1.668×10^{16}	26.5	22.6
61	6.916×10^{18}	1.234×10^{15}	26.5	20.7

The Arrhenius relationship for kinetic reaction rates is expressed as

$$k = k' e^{-E_a/RT} \quad (4)$$

Note that small changes in E_a can result in significant changes in the rate constant k . Therefore, a more appropriate analysis is to compare k observed at each of the storage temperatures with k computed from the manufacturer's kinetic parameters, using equation (4).

Table 13 is a summary of that comparison, where all values of k compare favorably with a maximum difference of 4.0% accuracy for MC 61 at 7.2°C. Therefore, the two MC's (57 and 61) evaluated performed reliably.

Table 13. Summary comparison of reaction rate constants at three constant temperatures.

Temperature	MC 57		MC 61	
	Observed	Reported	Observed	Reported
1.7°C	0.0154	0.0154	0.0309	0.0316
4.5°C	0.0279	0.0279	0.0554	0.0554
7.2°C	0.0404	0.0418	0.0781	0.0816

The two TTIPs of MC 57 and 61 evaluated in the lab study performed reliably with respect to first order reaction rates over the range of reflectance values encountered. Observed values for reaction rates and E_a agreed within 15 to 20% of those reported by the manufacturer.

B. SALADS

Quality parameters of salads which were sensitive to thermal history and significant to shelf life were determined in a controlled temperature storage study. Salad quality was evaluated on the basis of physical and microbial characteristics. A typical data collection sheet for physical characteristics is shown in Appendix I.

Physical Characteristics

Effect of Vibration. Three stacks of shippers containing salads were stacked 15 rows high and vibrated as described in Experimental

Design, page 23. Salads were wrapped with stretch wrap around the sides, but not over the top. Except for salads in the top two rows, there were no significant differences noted in the physical characteristics (syneresis, separation, and color) of vibrated vs. unvibrated salads, at any of the three storage temperatures, during the length of the study. The top two rows experienced considerably more vibration than did the lower rows, due to lack of stretch-wrap constraint. These salads exhibited a greater degree of separation and syneresis than did salads in the lower rows. However, it was determined at a later date that for retail distribution, pallets of salads are stretch-wrapped securely over the top layers. It is unlikely that vibration effects encountered in normal truck transportation have a temperature-dependent or temperature-related contribution to salad quality.

Syneresis and Separation. Syneresis was defined as the expulsion of water from the salad or salad dressing.

Separation was defined as the breakdown of emulsion in the salad dressing.

Syneresis and separation were judged qualitatively as: (-) absent, (/) slight; (+) definite.

Evaluations of the vibrated salads in regard to separation and syneresis are tabulated in Appendix V. A score of 0 was assigned to salads which exhibited no evidence of syneresis or separation; 0.5 for slight evidence, and 1.0 for definite evidence. Table 14 shows total scores for each salad variety as observed over the period of the study; and total scores for all varieties (vibrated and non-vibrated) at each temperature.

Table 14. Summary of Appendix V. Scores for syneresis and separation in salads.

	Syneresis			Separation		
	1.7°C	4.5°C	7.2°C	1.7°C	4.5°C	7.2°C
CSA	0.5	1.5	1.0	0.5	2.0	1.5
HCCS	1.0	1.5	5.0 ^{^*}	0	0	0.5
HCS	0	0	0	0	0	0
IPS	0	0	2.0	1.5	1.5	5.0 [^]
OFPS	2.0	0.5	2.5	0	0.5	2.0
SMS	3.0	4.5 [^]	4.0 [^]	3.0	4.0 [*]	6.0 ^{^*}
SPS	3.0	3.0	4.0 ^{^*}	2.0	2.5	3.5 [*]
TDFS	1.0	0	3.0	0	0	3.0
VGS	0	0	2.5	0.5	0	1.0
Total Vibrated	10.5	11.0	24.0	7.5	10.5	22.5
Total Non-vibrated	9.5	11.0	23.5	8.0	10.0	21.0

*Indicates total score ≥ 2.0 on or before 'expiration' date.

[^]Indicates consistent syneresis or separation at or near 'expiration' date.

Scores: (-)=0; (/)=0.5; (+)=1.0

A review of the data listed in Appendix V shows that four of the salad varieties (HCCS, IPS, SMS, and TDFS) exhibited tendency toward increasing syneresis or separation with increasing time. All other salad varieties did not show consistent tendencies toward syneresis or separation until they had exceeded the 23 day shelf life. Only three salad varieties (HCCS, SMS, and SPS) had total scores $>$ or $=$ 2.0 on or before the 23 day 'expiration'.

For four types of salads (HCCS, IPS, SPS, and VGS), scores for syneresis increased with increasing storage temperature over time. For six types of salads (HCCS, IPS, OFPS, SMS, SPS, and TDFS) separation increased with increasing temperature.

Although there may be a slight trend toward increasing syneresis and/or separation with time and/or temperature for some salads, results are subjective and data are not conclusive enough to facilitate development of a correlation between syneresis or separation and thermal history and vibration.

Color. Salads were observed for overall color during shelf life and beyond. Results of evaluations on color are tabulated in Appendix VI. Seven (HCCS, HSC, IPS, SMS, SPS, TDFS, and VGS) of the nine salads exhibited a trend toward color loss with increasing time and/or temperature, as shown in Table 15.

Five types of salads (HCCS, IPS, SMS, SPS, and VGS) exhibited a definite loss of color was a function of thermal history. For these salads, color was judged 'good' or 'bright' initially; then 'slightly dull', followed by 'dull'. The first loss of color (judgement of 'slightly dull') was determined earlier at higher temperatures (7.2 and

Table 15. Summary of color evaluations for selected salads.*

Salad	Storage Temp.	Shelf Life Day Color Loss First Observed		
		7.2°C	4.5°C	1.7°C
HCCS		19	19	23
HCS		27	24	24
IPS		20	24	24
SMS		23	24	27
SPS		22	23	23
TDFS		22	23	20
VGS		23	24	34
Average day of first color loss*		21.4	22.8	26.2

*Excluding HCS, TDFS, due to inconsistency of data.

4.5⁰C) than at the lower, 'optimum' storage temperature of 1.7⁰C.

For six types of salads (HCCS, IPS, SMS, SPS, TDFS and VGS) stored at 7.2⁰C, color loss was evident BEFORE the 23 day 'expiration' date. At storage of 4.5⁰C, three salad varieties (HCCS, SPS, and TDFS) showed color loss before expiration, and at 1.7⁰C, only HCCS and TDFS exhibited color loss before expiration.

For two salad varieties (CSA and OFPS) color change as a function of time and/or temperature was not evident during the lab study. CSA is the only one of the nine salads that does not have many different colored components. It is composed of white chicken meat, almonds, mayonnaise, and finely chopped celery. Color of CSA was evaluated as 'bland' or 'dull' throughout the study. OFPS components consisted of potatoes (white), hard cooked eggs (white and yellow), green pepper (green), and pimento (red). Loss of color was not noted except in one sample, and may be due to the effect of preservatives in the formulation.

There is a general tendency toward first order rate loss of color of certain salad components over time and with increasing storage temperature. This tendency is illustrated in Figure 7, where average first day of color loss at each temperature is plotted against inverse of absolute temperature. The plot is a straight line which obeys the Arrhenius relationship. The evaluations in this study were subjective, but consistent. A more objective means of measuring color loss was used in the field study.

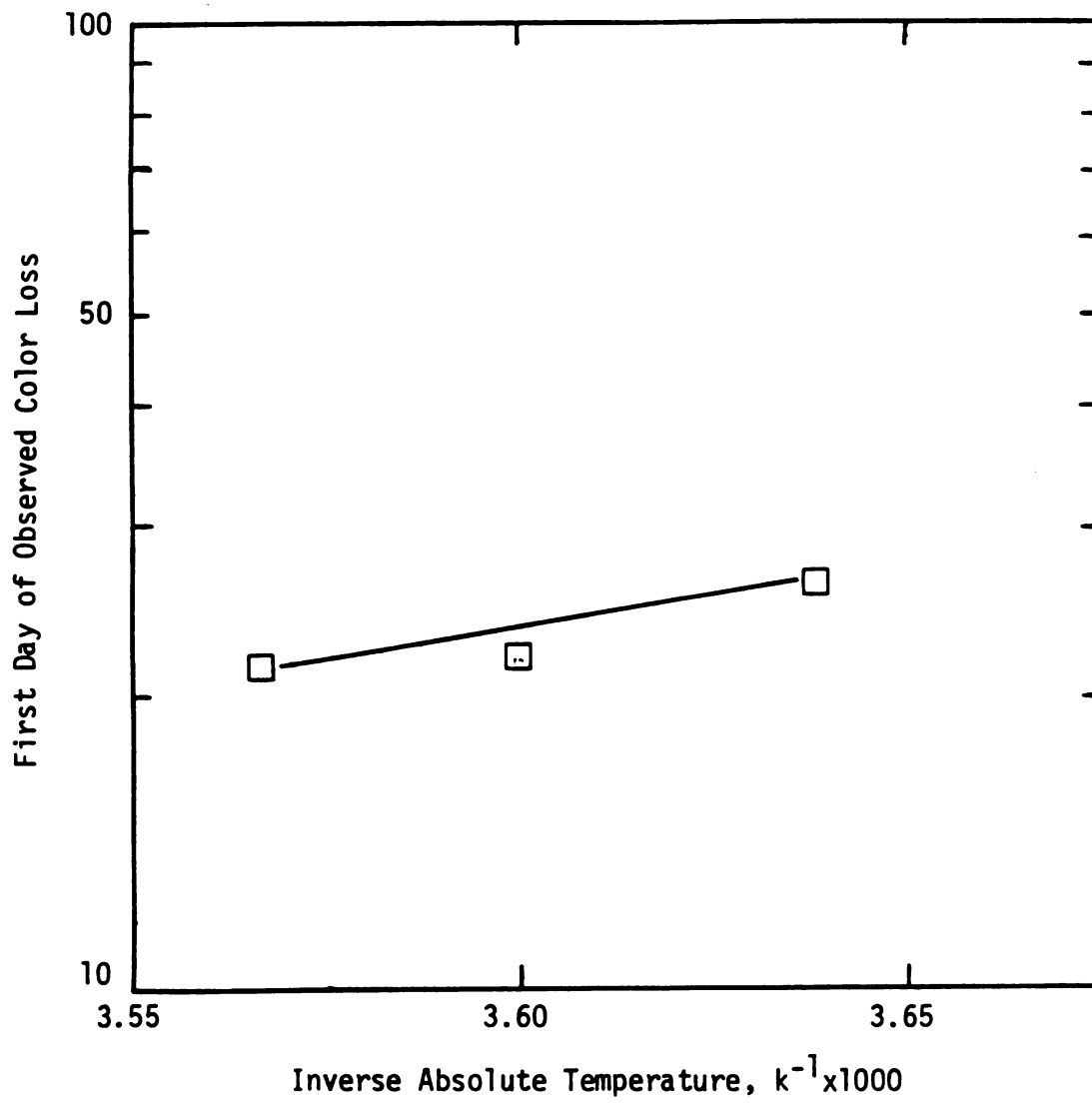


Figure 7. Plot of Average First Day of Observed Color Loss vs. Inverse Absolute Temperature.

Microbiological Characteristics

Salads were evaluated for microbiological populations which might affect quality or shelf life. Samples of salads stored at each of three temperatures (1.7, 4.5, and 7.2°C) were plated for total, yeast and mold, and psychrotrophic counts during shelf life and beyond. A complete listing of microbial counts is shown in Appendix VII.

A review of all counts tabulated in Appendix VII indicates no general tendency of microbial counts to change as a function of time or storage temperature. Yeast and mold counts and psychrotrophic counts are very low, generally less than 100 per gram for all varieties at all storage conditions. Total plate counts, as expected, are somewhat higher, generally from 10^2 to 10^4 per gram. Total counts do not show appreciable increase over time for any of the samples plated. There is a general tendency for salads stored at the lower temperature (1.7°C) to exhibit slightly higher counts per gram than salads stored at 7.2°C. This is due to the presence of sorbates and benzoates in the salads, which have a greater antimicrobial effect at the warmer temperature (Zink, 1985). PH of the salads ranged from 3.8 to 4.9, and this may also have been responsible for low counts.

The results of the microbiological study do not indicate an obvious relationship between microbial count and salad quality. Microbial counts did not increase appreciably over time, and were slightly higher with optimum storage temperature.

II. FIELD STUDY

Changes in salad quality during commercial distribution were measured and correlated with TTIP reflectance value. Use of the TTIP in identifying areas of thermal abuse in the distribution channel was demonstrated.

A. SALAD QUALITY

Salads had an expected shelf life of 23 days. Packages were code dated with an appropriate 'use by' date and labeled with pertinent storage information ('...must be kept refrigerated').

Salads were retrieved from the grocery warehouse on approximately Day 4; and from retail stores on approximately Days 16 and 23. Microbial, sensory, and color analyses were performed on selected salads in each of three production lots according to the scheme outlined in Table 6. Microbial and sensory evaluations were performed on 'variables' (salads retrieved from retail distribution) and on 'controls' (salads stored at Campbell Institute for Research and Technology under optimum conditions - 1.7°C - immediately after manufacture). Color evaluations were performed on variable salads only.

Microbiological

Salads were evaluated for microbiological counts on approximately Days 6, 18, 24, and 34 after manufacture. Day 6 was approximately the

first day the salads were likely to be purchased at retail. Day 18 represented the time a product may have been in retail distribution for approximately two days; Day 24 was immediately after expiration; and Day 34 was 10 days past expiration.

Salads were enumerated for total, yeast and mold, lactobacillus, psychrotrophic, and coliform counts. Complete data for total, lactobacillus, and psychrotrophic counts are tabulated in Appendix VIII. Coliform and yeast and mold counts for all varieties of variables and controls tested were extremely low ($<10/\text{gram}$) during shelf life and beyond. The highest coliform count for all salads tested was 20/gram for Ham and Cheddar Cheese Salad (HCCS), Variable, at 25 days. All samples except one (Italian Pasta Salad, Variable) had yeast and mold counts less than 30/gram. The count for IPS (Variable) at 34 days was 100/gram.

Total, lactobacillus, and psychrotrophic counts were acceptable for variable and control samples of all varieties tested before code date. For six varieties tested after code date (HCS, IPS, VGS, OFPS, SMS, and SPS), only one, OFPS (Variable), had an unacceptable count. Count for OFPS (Variable) at Day 34 was $4.3 \times 10^8/\text{gram}$, while for OFPS (Control) was $7.0 \times 10^3/\text{gram}$. Comparison of variable and control counts for each variety reveals little difference. In general, counts for variables were slightly higher than those for controls; in most cases, the difference being one order of magnitude or less. In a comparison of counts between varieties, it is interesting to note that Chicken with Almonds Salad (CSA) had the lowest counts of all varieties. CSA was the only one of the salads not preserved with benzoates or

sorbates.

Microbial populations did not reach unacceptable levels during expected salad shelf life, probably due to the use of benzoate and sorbate preservatives. It was not possible to establish a relationship between microbial populations and thermal history that could have been correlated with TTIP performance.

Sensory

The nine varieties of salads were evaluated for overall flavor quality by a trained panel of 18 to 20 judges on Days 6 and 22 after manufacture. One variety (SPS) was also judged 12 days after code date. Indicators were scanned and mean reflectance values recorded at times of sensory evaluations. Statistical summaries of mean flavor scores and normalized reflectance values are provided in Appendix IX.

Flavor Scores. Analysis of flavor score data (Brusco, 1985) for all nine varieties yielded the following:

1. All varieties of salads tested following 22 days storage at optimum conditions of 1.7°C and commercial storage conditions at variable temperatures were of acceptable flavor quality. One variety (SPS) was tested following 35 days storage at optimum and variable conditions; it was also found acceptable.

2. Results of analysis of variance for all salads tested are listed in Table 16. From Type III Sums of Squares, which gives the relative impact of each variable (age, variety, storage temperature) it is obvious that there were significant effects due to age, variety and age-variety interaction, but no significant temperature interaction.

Table 16. Salads sensory evaluation; analysis of variance.

Dependent Variable: Score

Source	DF	Sum of Squares	Mean Squares	F Value	OSL*
Model	26	119.93	4.61	4.84	0.16
Error	667	636.27	0.95		
Corrected				R-Squared	
Total	693	756.19		0.16	

Source	DF	Type III S.S.	F Value	OSL*
Age	1	34.48	36.32	0.0001
Temp	1	3.04	6.34	0.0747
Product	8	46.03	5.81	0.0001
Age/Product	8	17.72	3.72	0.0184
Temp/Product	8	6.48	0.85	0.5592

*OSL is probability of a greater F.

Salads exhibited similar effects due to age (scores decreased as salads aged) but not necessarily due to storage temperature. The R-squared, which in this analysis accounts for five variables, is very small. This is partly due to the extreme variation in individual scores as indicated by standard deviations listed in Appendix IX.

Due to problems in transmitting and transferring data, reflectance values for CSA, HCCS, and TDFS were lost and the flavor scores for these varieties could not be correlated with reflectance values. Flavor scores for six varieties (HCS, IPS, VGS, OFPS, SMS, and SPS) were correlated with reflectance values.

The large variability in individual flavor scores resulted in a low F value for linear correlation of reflectance with flavor scores. Recognizing this variability as an inherent tendency in sensory evaluation, MEAN flavor scores were used in attempting to establish a correlation between flavor score and reflectance value. Linear regression analysis (SAS, Barr et al., 1976) was used to correlate mean flavor scores to normalized TTIP reflectance values. Table 17 lists correlation coefficients for six salads analyzed individually, and for the same six salads pooled.

Generally, sensory scores were positively correlated with reflectance. Two varieties of salads (IPS and SPS) yielded a correlation coefficient $r > 0.9$ while three other varieties (HCS, OFPS, and SMS) exhibited $r > 0.8$. Plots of mean scores vs. normalized reflectance values for IPS, SPS, and for six salads pooled are shown in Figures 8, 9 and 10.

Table 17. Linear regression of mean sensory flavor score vs. normalized reflectance values.

Salad	Correlation Coefficient (r)
HCS	0.860
IPS	0.923
VGS	0.568
OFPS	0.874
SMS	0.846
SPS	0.910
ALL	0.662

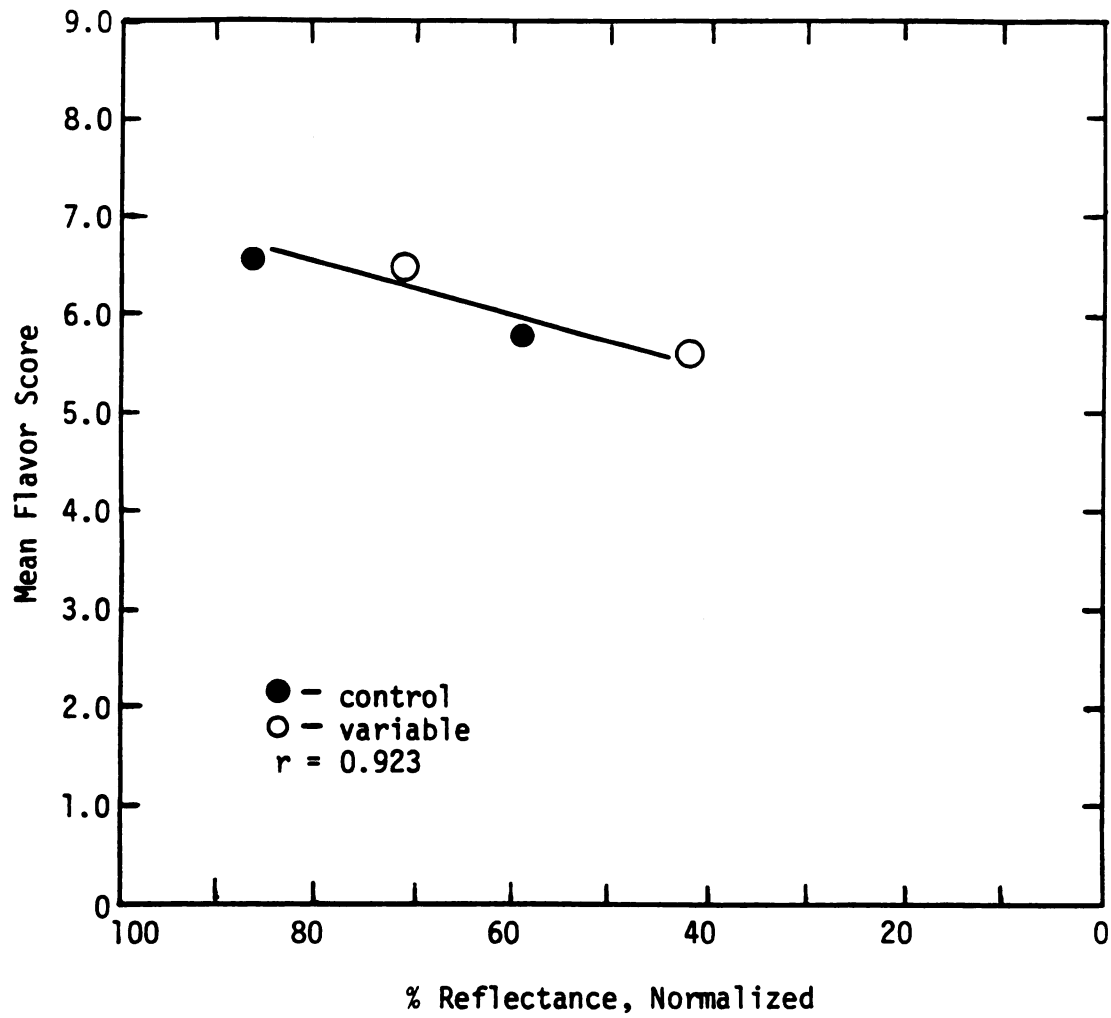


Figure 8. Italian Pasta Salad Mean Flavor Scores vs. Normalized Reflectance.

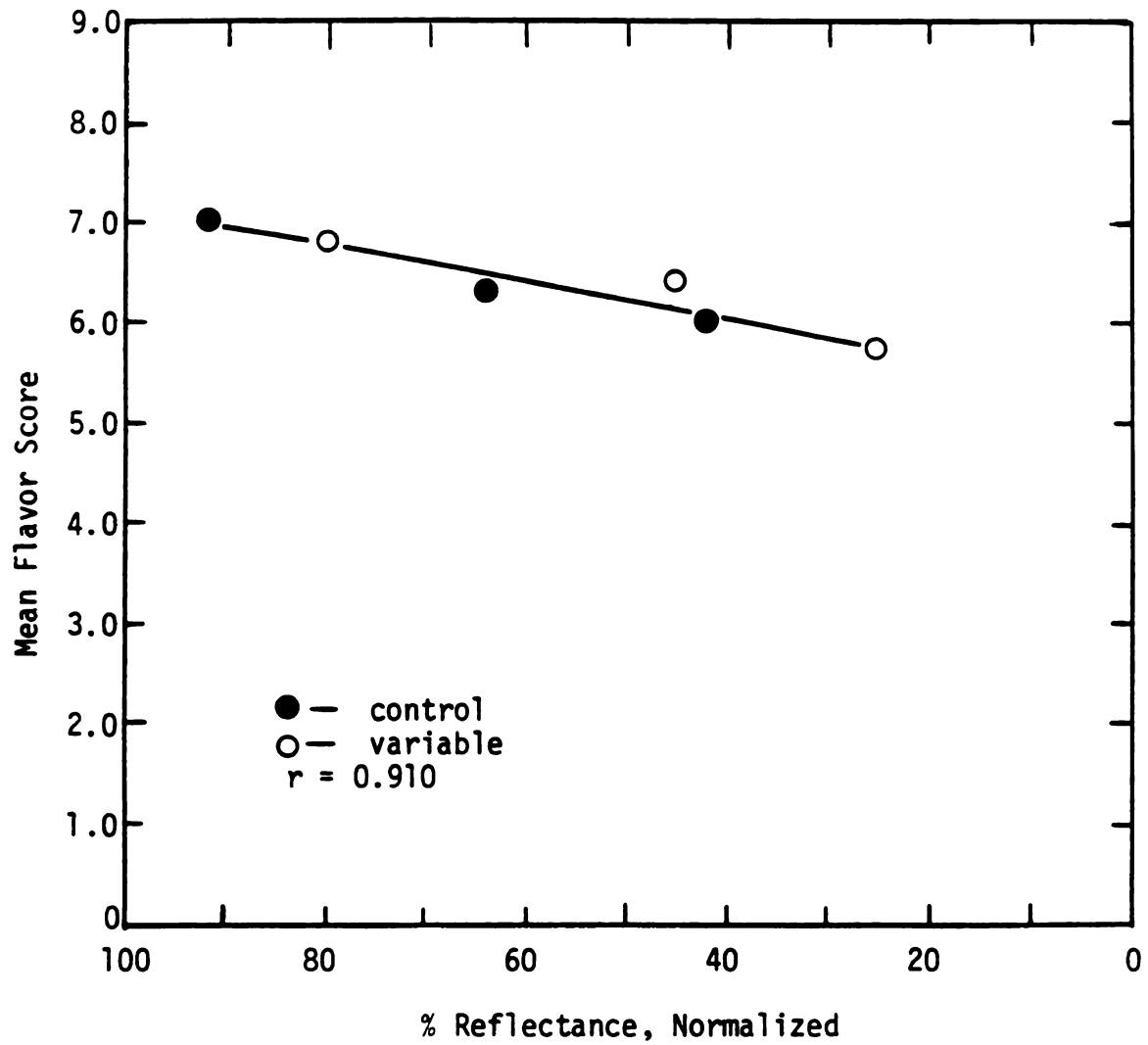


Figure 9. Seafood Pasta Salad Mean Flavor Scores vs. Normalized Reflectance.

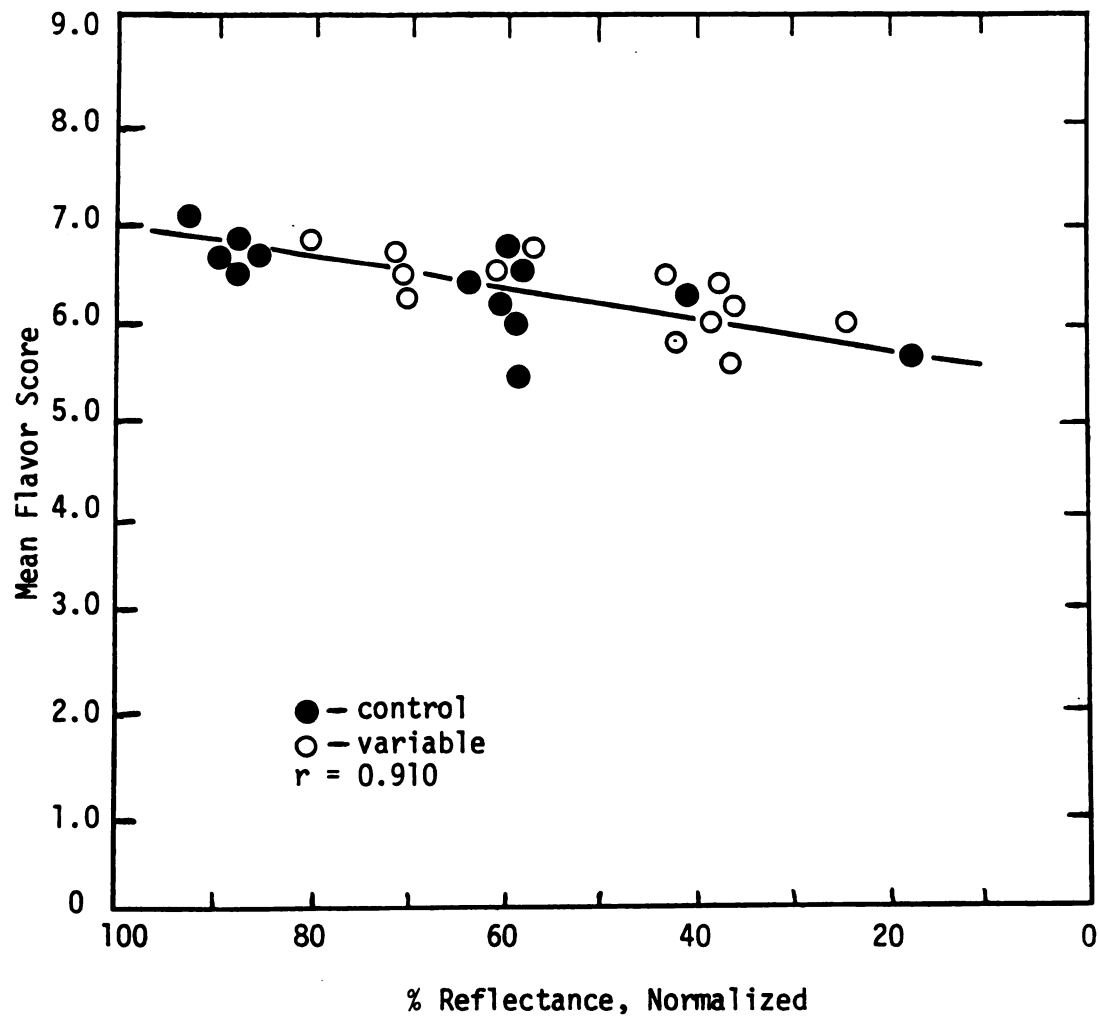


Figure 10. Mean Flavor Scores vs. Normalized Reflectance for Six Salad Varieties.

Analysis of sensory evaluation data indicated that age (time) of product had greater significance in scoring than did storage conditions (temperature). Scores for salads tested near or after 'expiration' of shelf life (Days 22 and 35) were significantly lower than scores for 'fresh' salads (Day 6). However, none of the salads tested were judged to be unacceptable. This suggests that none of the salads was subjected to extreme thermal abuse. Due to large variability in individual scores, linear correlation of reflectance values with individual flavor scores was poor. However, MEAN flavor scores were found to be positively correlated with reflectance, with $r > 0.84$ for five of six salads tested.

Color

Fennema (1976) has shown that almost any type of food processing (thermal, dehydration, freezing, irradiation) alone or combined with storage contributes to the deterioration of chlorophyll. Deterioration in chlorophyll can be quantified by changes in the maxima (660 nm) of the absorption spectra (AOAC, 1975). Chlorophyll was extracted from green peppers, celery, and broccoli in different salad varieties according to the procedure outlined in Appendix III (Fisher and Barr, 1985).

Table 18 is a list of absorbance and normalized reflectance values for each of five salads containing green pepper. A review of the data shows that as absorbance (Abs) decreases (i.e., as chlorophyll deteriorates), reflectance values also decrease. Least squares regression analysis was used to develop a correlation between Abs and

Table 18. Absorbance values (triplicate samples) of total chlorophyll extracted from green peppers in five salad varieties during shelf life.

	Day 4	Day 18	Day 25
<u>Holiday Cole Slaw</u>			
% R	65	35	29
ABS	0.18	0.057	0.083
	0.22	0.075	0.083
	0.26	0.066	0.083
Avg.	0.22	0.066	0.083
<u>Old Fashioned Potato Salad</u>			
% R	56	33	
ABS	0.201	0.11	
	0.098	0.081	No product available
	0.105	0.051	
Avg.	0.13	0.081	
<u>Italian Pasta Salad</u>			
% R	59	40	25
ABS	0.33	0.048	0.039
	0.50	0.065	0.075
	0.35	0.086	0.058
Avg.	0.39	0.066	0.057

Seashell Macaroni Salad

% R	62	44	25
ABS	0.51	0.105	0.025
	0.47	0.12	0.045
	0.49	0.052	0.057
Avg.	0.49	0.092	0.042

Ham and Cheddar Cheese Salad

% R	75	49	30
ABS	0.28	0.057	0.059
	0.53	0.089	0.075
	0.42	0.080	0.056
Avg.	0.41	0.075	0.063

% R, and resulted in the best fit relationship of the form:

$$\ln \text{ Abs} = a (\% R) + b \quad (5)$$

Data from individual chlorophyll analyses for all five salads are plotted against Reflectance values in Figure 11. Figure 12 is a somewhat simpler version of Figure 11, showing the average values of Abs vs. % normalized Reflectance for each of the five salads. R-squared in both cases was reasonably good, 0.792 for individual absorbance values vs. % normalized R, and 0.723 for average absorbance values vs. % normalized R. Of the five salads considered individually, average values of Abs correlated well with % R, for example, R-squared = 0.952 for SMS variety which are plotted in Figure 12.

Results of analyses of chlorophyll extraction from celery and broccoli are inconclusive. Table 19 lists results of chlorophyll analysis for celery in 3 salad varieties. For HCCS, absorbance values at Days 18 and 25 are nearly the same (0.057 and 0.058), and for CSA, values at Days 18 and 25 are exactly the same. Chlorophyll concentration in celery is less than in green pepper, and measurements at lower levels are subject to greater error. The amount of celery available for extraction was also small (usually no more than 15 grams), and may also have been a source of error.

Table 20 lists results of chlorophyll extraction from broccoli in one salad variety. The absorbance values for Day 18 are not statistically different from those for Day 4, indicating possible error in procedure. Day 25 and Day 34 values are somewhat less, suggesting the possibility of a relationship similar to that of green pepper.

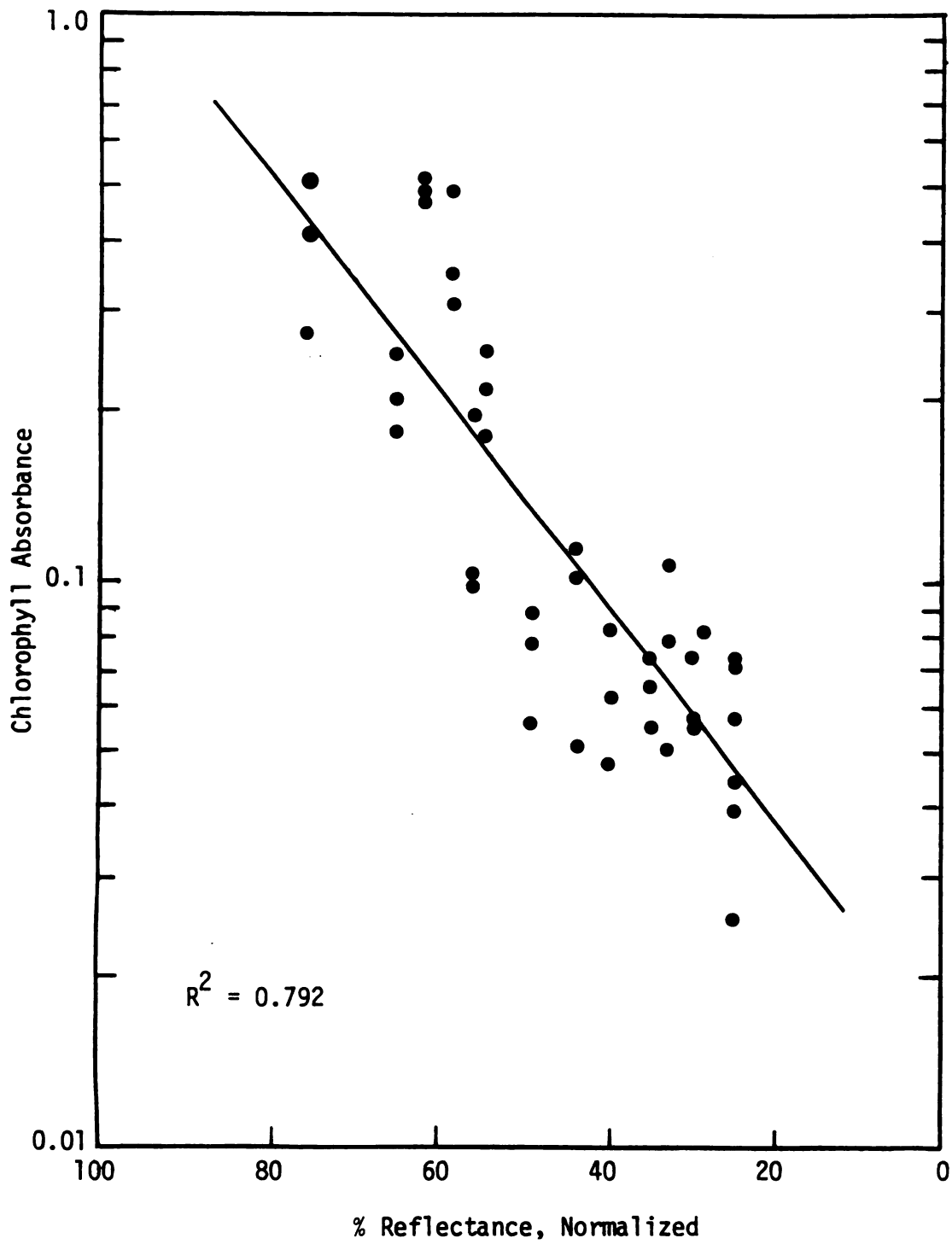


Figure 11. Chlorophyll Absorbance (Values from Individual Trials) vs. % Reflectance (Normalized) for Five Salad Varieties Containing Green Pepper.

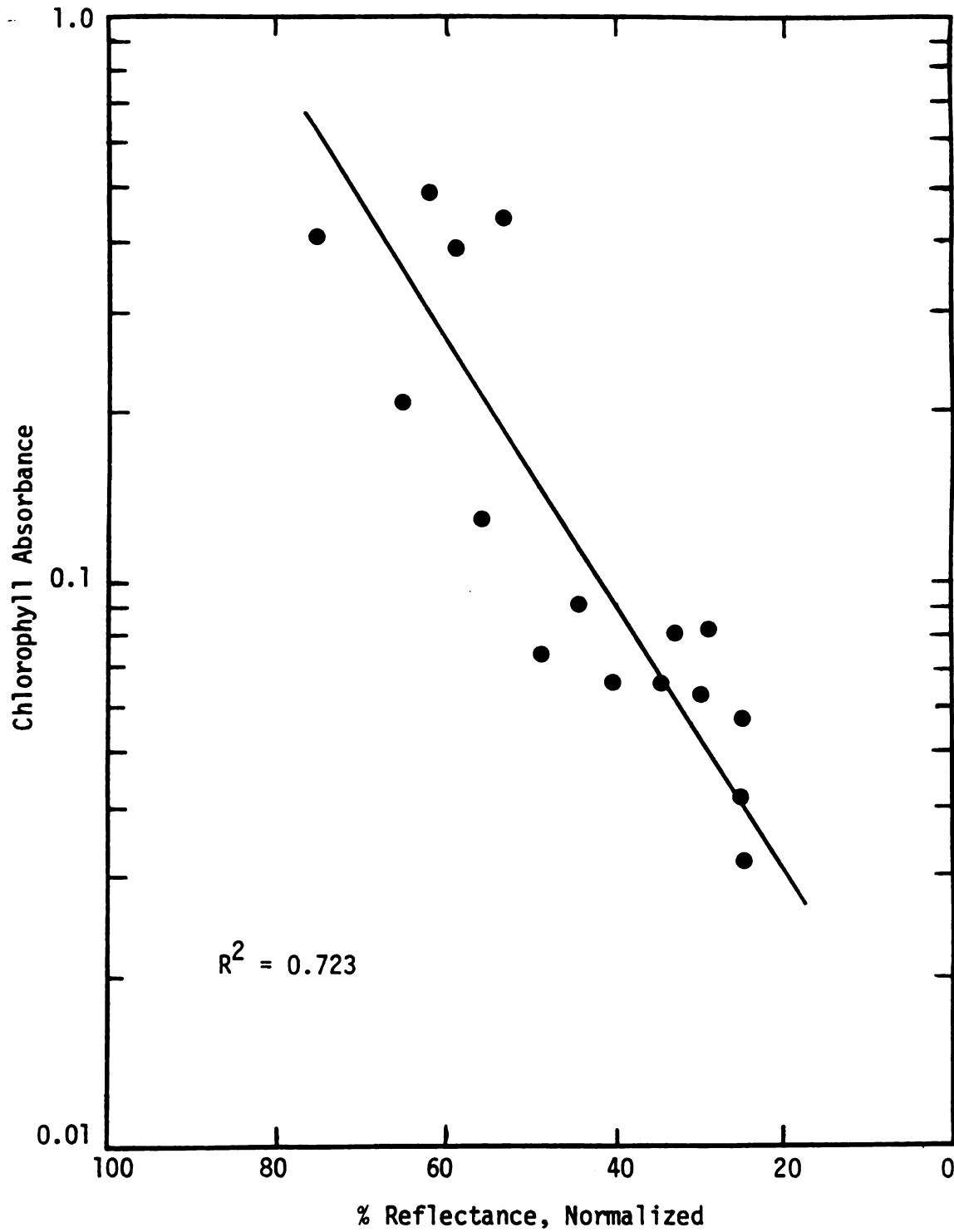


Figure 12. Chlorophyll Absorbance (Average Values) vs. % Reflectance (Normalized) for Five Salad Varieties Containing Green Pepper.

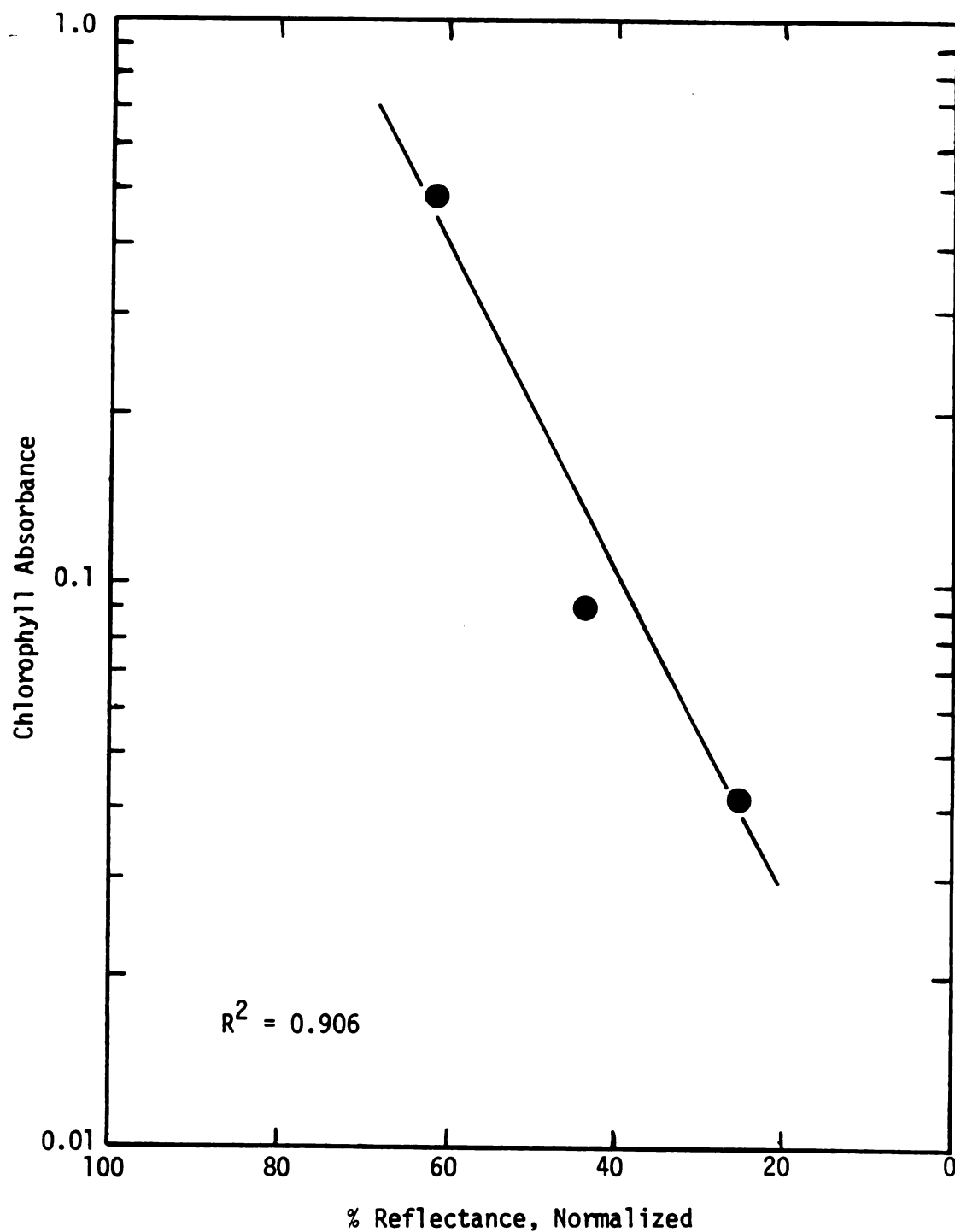


Figure 13. Chlorophyll Absorbance vs. % Reflectance (Normalized) for Green Pepper in Seashell Macaroni Salad.

Table 19. Absorbance values (triplicate samples) of total chlorophyll extracted from celery in three salad varieties during shelf life.

	Day 4	Day 18	Day 25
<u>Ham and Cheddar Cheese Salad</u>			
% R	75	49	30
ABS	0.11	0.072	0.053
	0.13	0.057	0.059
	0.11	0.042	0.063
Avg.	0.12	0.057	0.058
<u>Chicken with Almonds Salad</u>			
% R	75	38	33
ABS	0.30	0.040	0.050
	0.32	0.030	0.040
	0.16	0.040	0.050
Ave.	0.26	0.040	0.040
<u>Old Fashioned Potato Salad</u>			
% R	58	33	
ABS	0.12	0.12	
	0.045	0.102	No product available
	0.095	0.036	
Avg.	0.087	0.086	

Table 20. Absorbance values (triplicate samples) of total chlorophyll extracted from broccoli in vegetable garden salad during shelf life.

% R = Normalized Reflectance Values

	<u>Vegetable Garden Salad</u>			
	Day 4	Day 18	Day 25	Day 34
% R	60	44	27	24
ABS	0.15	0.14	0.12	0.092
	0.14	0.14	0.091	0.101
	0.13	0.17	0.14	0.12
Avg.	0.14	0.15	0.12	0.104

Each of the salad varieties is a mixture of different components - vegetables, dressing, preservatives, etc. It is not known what effect the particular 'mix' of one formula may have on chlorophyll deterioration in one vegetable as opposed to another. Data for chlorophyll deterioration in green peppers in salads was positively correlated with TTIP reflectance, while no significant correlations were found between chlorophyll in celery or broccoli and reflectance. Due to the difference in chlorophyll concentration in different vegetables, a refinement of the procedure used for chlorophyll extraction may be in order.

B. THERMAL ABUSE

In the field study, salads labeled with indicators were traced through commercial distribution and retrieved at intervals. Indicators on salad packages were scanned and reflectance values of the TTIPs were recorded. Indicators were scanned on Day 0 and a baseline established for each salad variety. All reflectance data were normalized by dividing the mean reflectance by the baseline. This facilitated standardized comparisons between salads of different varieties and with different manufacture dates.

Table 21 lists TTIP mean reflectance values recorded on several days for two groups of salads from one variety Holiday Cole Slaw (HCS), manufactured on a Thursday. Figure 14 is a plot of those data. One group (solid circles) was stored under controlled conditions immediately after manufacture, while the other (hollow circles) went through normal distribution. Day 0 (Thursday) values for both

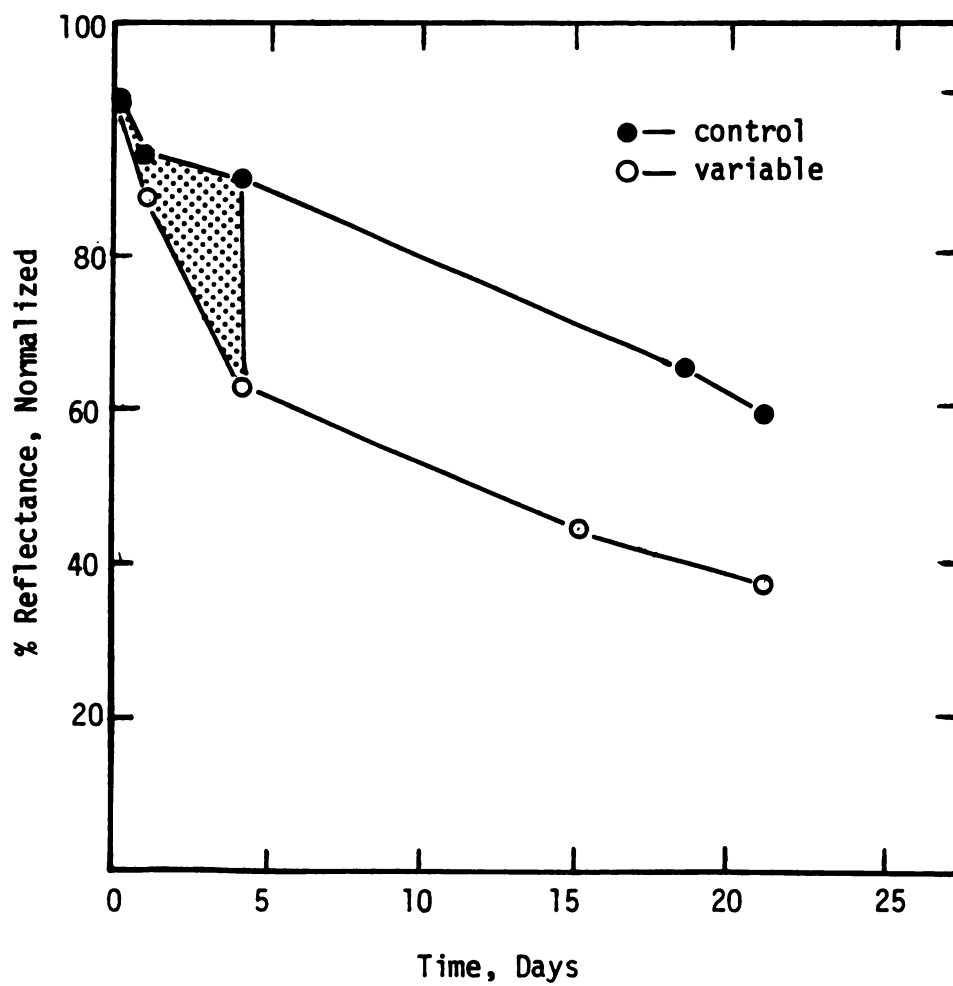


Figure 14. Normalized Reflectance Values vs. Time for Control and Variable Holiday Cole Slaw Salads.

Table 21. Reflectance values for control and variable Holiday Cole Slaw Salads during shelf life.

Day	0	1	4	15	19	22
Control	100	93	90	-	65	59
Variable	100	85	61	44	-	37

groups were recorded at the manufacturing site. All control values were recorded at Campbell Institute for Research and Technology (CIRT), where salads were stored at a constant temperature of 1.7°C . Variable salads were retrieved and indicators scanned at the manufacturing plant on Day 1 (Friday), the grocery (Safeway) warehouse on Day 4 (Monday), and from retail stores on later days.

The shaded area in Figure 14 indicates an extreme difference in thermal treatment of control and variable salads between Days 0 and 4. Between Days 0 (Thursday) and 4 (Monday), salads were held at the manufacturer's warehouse (in Texas) for two days and then shipped by refrigerated truck to the grocery warehouse in Colorado. Indicators show a loss of 15% Reflectance between Days 0 and 1, while still at the manufacturing plant, and an additional loss of 24% Reflectance between Days 1 and 4. The time between Days 1 and 4 included some time at the plant, and transport time between Texas and Colorado. This topic will be addressed in more detail later. Beyond Day 4, the slopes of the two lines are nearly parallel, indicating similar thermal history for both controls and variables for the remainder of the observed period.

Data from Table 21 are plotted in Figure 15, illustrating thermal history differences between variable and control salads. The dashed arrow indicates similar thermal treatments for controls and variables but at different times. Indicators on variable salads had a mean reflectance of 61% on Day 4, while indicators on control salads did not reach a comparable level (59%) until Day 22, a difference of 18 days.

Table 22 lists TTIP mean reflectance values recorded for controls and variables from another variety, Vegetable Garden Salad (VGS). VGS was manufactured on Friday of the same week as HCS previously discussed. VGS salads were stored and retrieved in the same manner as HCS salads. Figure 16 is a plot of reflectance values vs. time for VGS salad indicators, and illustrates the differences in thermal treatment of control and variables. Indicators on variable VGS salads show a loss of 30% Reflectance between Days 0 (Friday) and 3 (Monday). The shaded area in Figure 16 (indicating difference in thermal treatment between controls and variables) is considerably smaller than the shaded area in Figure 15, suggesting that salads manufactured on Friday and held until Saturday are subjected to less thermal abuse than salads manufactured on Thursday and held until Saturday. The dashed arrow illustrates that VGS variable salads on Day 3 had received equivalent thermal treatment to control salads at Day 15.

Figure 17 further illustrates the difference in thermal treatment of salads manufactured on Thursday and Friday. The left side of the graph illustrates the CHANGE in reflectance for indicators on salads manufactured on a Thursday, the right for salads manufactured on Friday

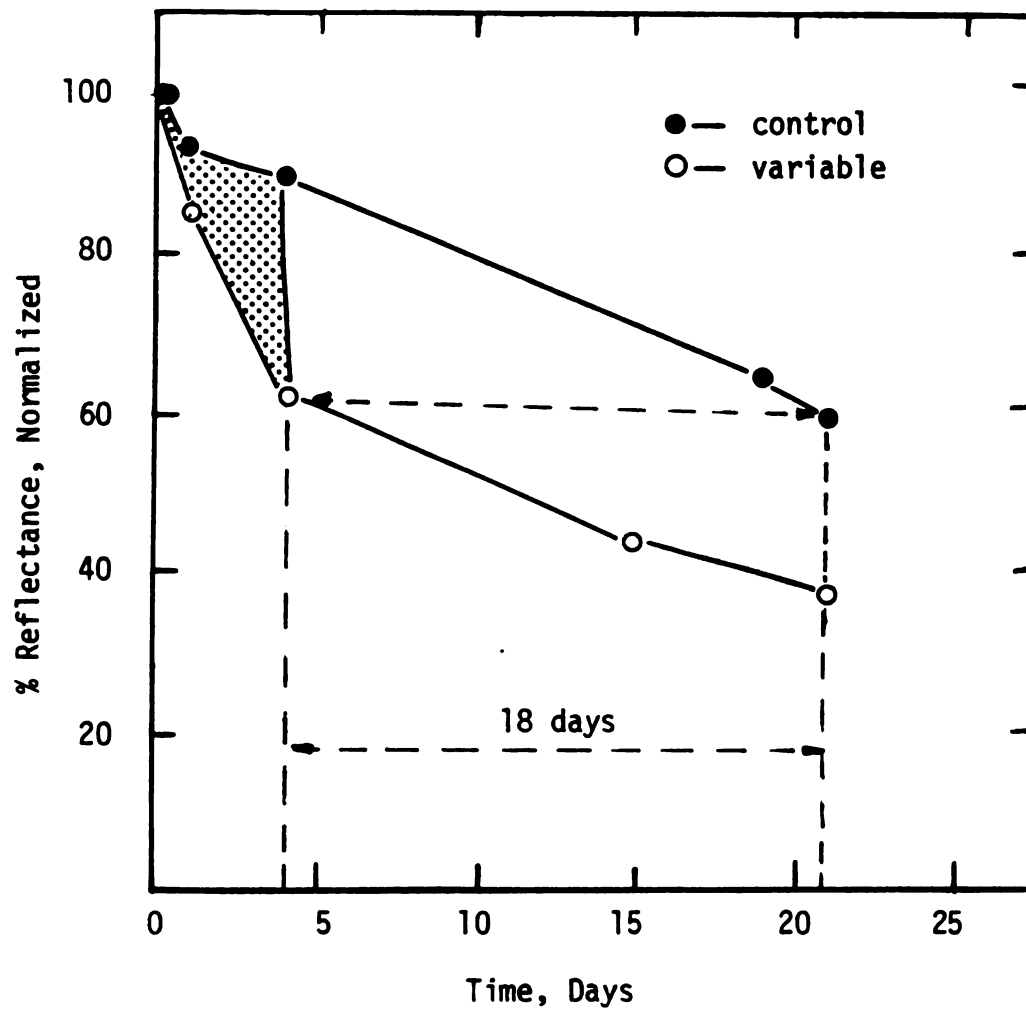


Figure 15. Comparison of Thermal Treatment for Control and Variable Holiday Cole Slaw Salads.

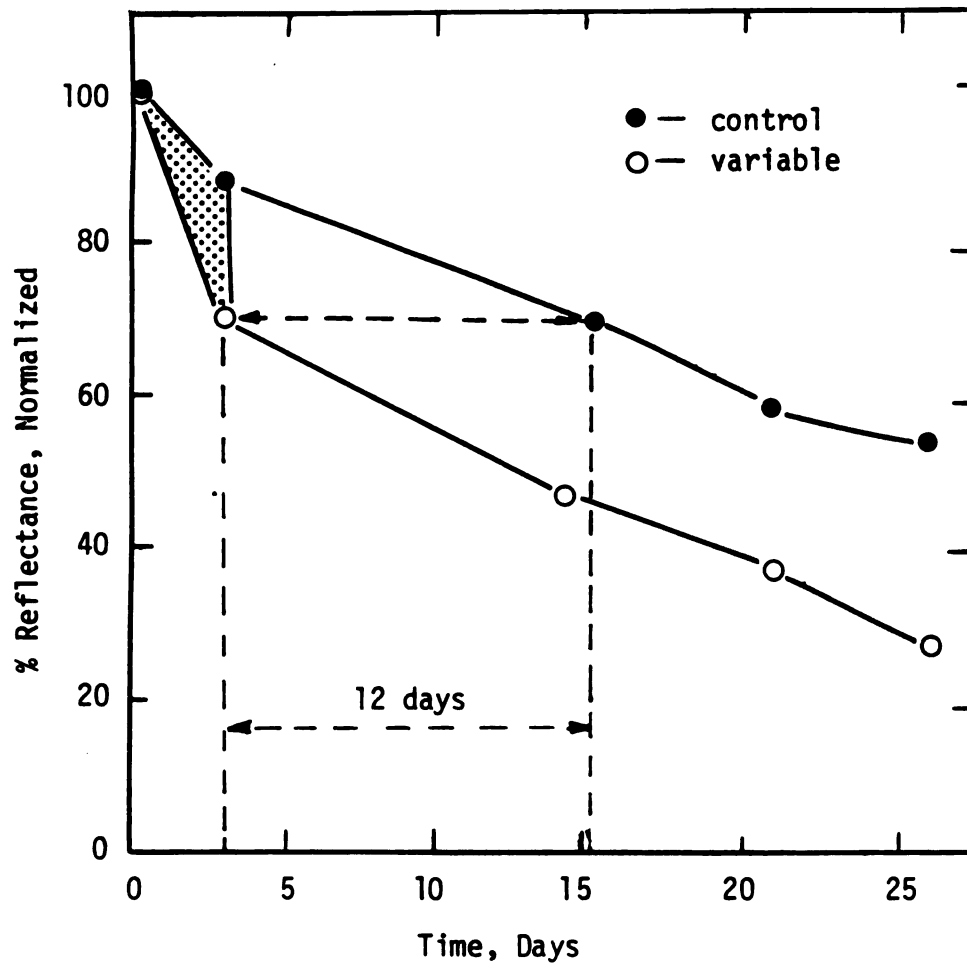


Figure 16. Normalized Reflectance Values vs. Time for Control and Variable Vegetable Garden Salads.

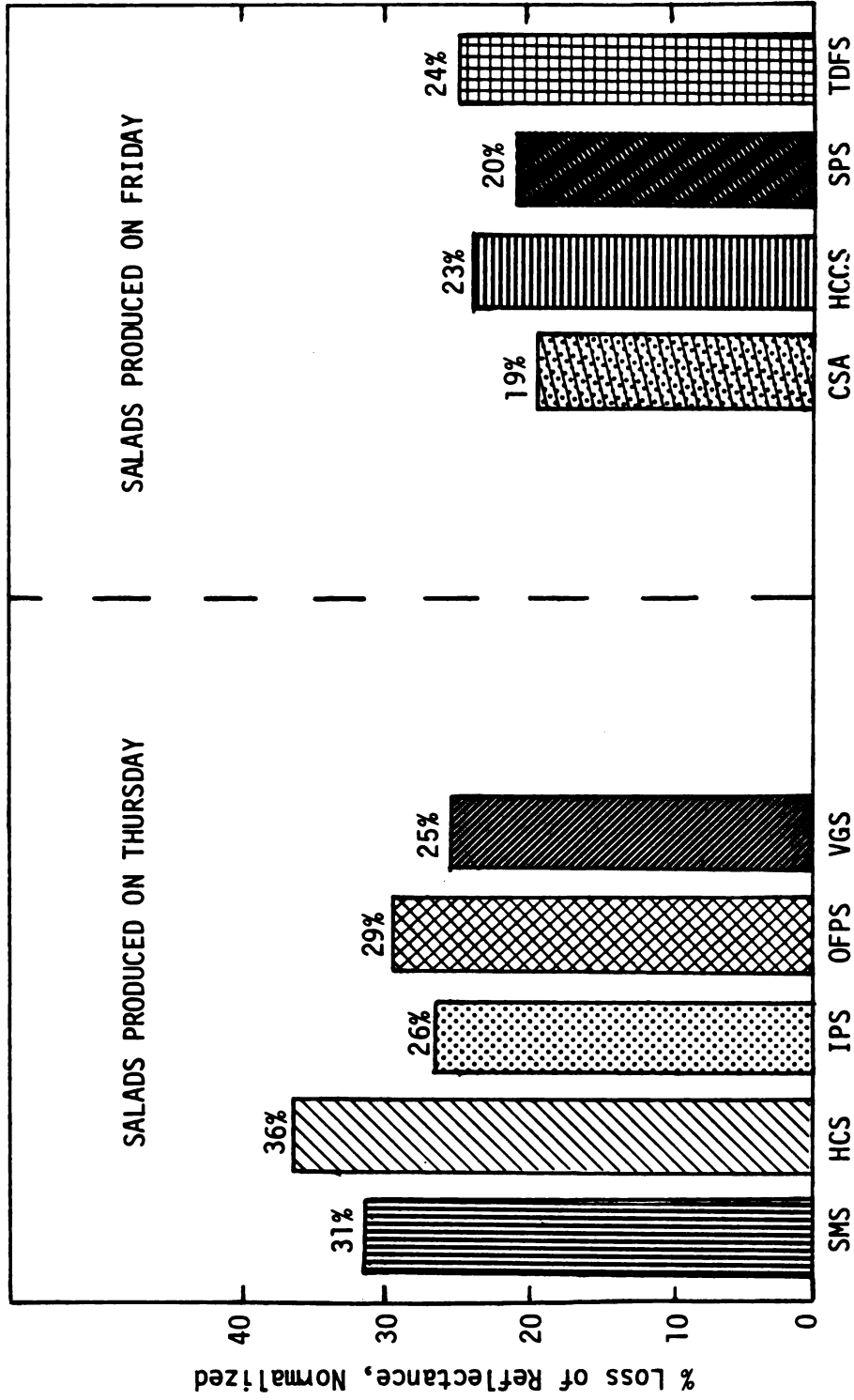


Figure 17. Comparison of Loss of Reflectance for Salad Varieties Produced on Two Days.

Table 22. Reflectance values for control and variable vegetable garden salads during shelf life.

Day	0	3	14	18	21	26
Control	100	88	-	66	59	54
Variable	100	79	47	-	37	27

of the same week. Note that indicators on the 'Thursday' salads, (SMS, HCS, OFPS, IPS, and VGS) have lost from 25% to 36% of initial reflectance, while 'Friday' salad indicators have lost 19% to 24%.

For all lots and varieties of salads traced through commercial distribution, the greatest loss of reflectance for a single time period occurred between time of manufacture and time of receipt at the grocery warehouse. Part of this time is spent at the manufacturing plant, and part on the truck, in transport. Recommended storage temperature at the plant is approximately 4.5⁰C, and on the truck is 1.7⁰C. Temperatures at the plant are expected to be somewhat higher than 'optimum' and to fluctuate due to normal warehouse activities. It was not possible to scan indicators at the time of exchange between the plant and the truck in order to pinpoint exactly where the greatest reflectance loss (thermal abuse) was occurring. However, trucks had been periodically monitored with time/temperature recorders (Kirwin, 1985) and found to be consistently maintained at 1.7⁰C. It has already been shown that indicators on salads manufactured on Thursday and held until Saturday lost a greater percentage of reflectance value than salads manufactured

on Friday. This is to be expected due to the longer holding period at the plant. Indicators on Old Fashioned Potato Salads (OFPS) manufactured on a Thursday and scanned on the following day (at the plant) showed a 14% loss of reflectance, as illustrated in Figure 18. By using reaction rate values determined in the lab study, the average temperature to which the product and indicators had been exposed during this period was calculated at 12°C (well above the recommended warehouse storage temperature of 4.5°C). These are the only data that shows measurements taken at the plant over a 24 hour period and may represent an isolated incident of thermal abuse. It does, however, suggest the need for further investigation.

Figure 19 illustrates the range of reflectance values for samples of OFPS manufactured as the same lot and purchased on Day 22 at five different retail locations. Reflectance value on Day 4 at the grocery warehouse was 71%, showing the greatest loss of reflectance for one time period. Mean reflectance values for indicators on salads purchased at the different retail stores ranged from 32% to 44%. Differences in reflectance values represent different thermal histories experienced by each group of salads between the warehouse and the retail stores.

TTIP indicators can be used to identify areas of thermal abuse. Reaction rates of the polymers can be used to calculate average temperature to which a product has been exposed between two points of indicator scanning.

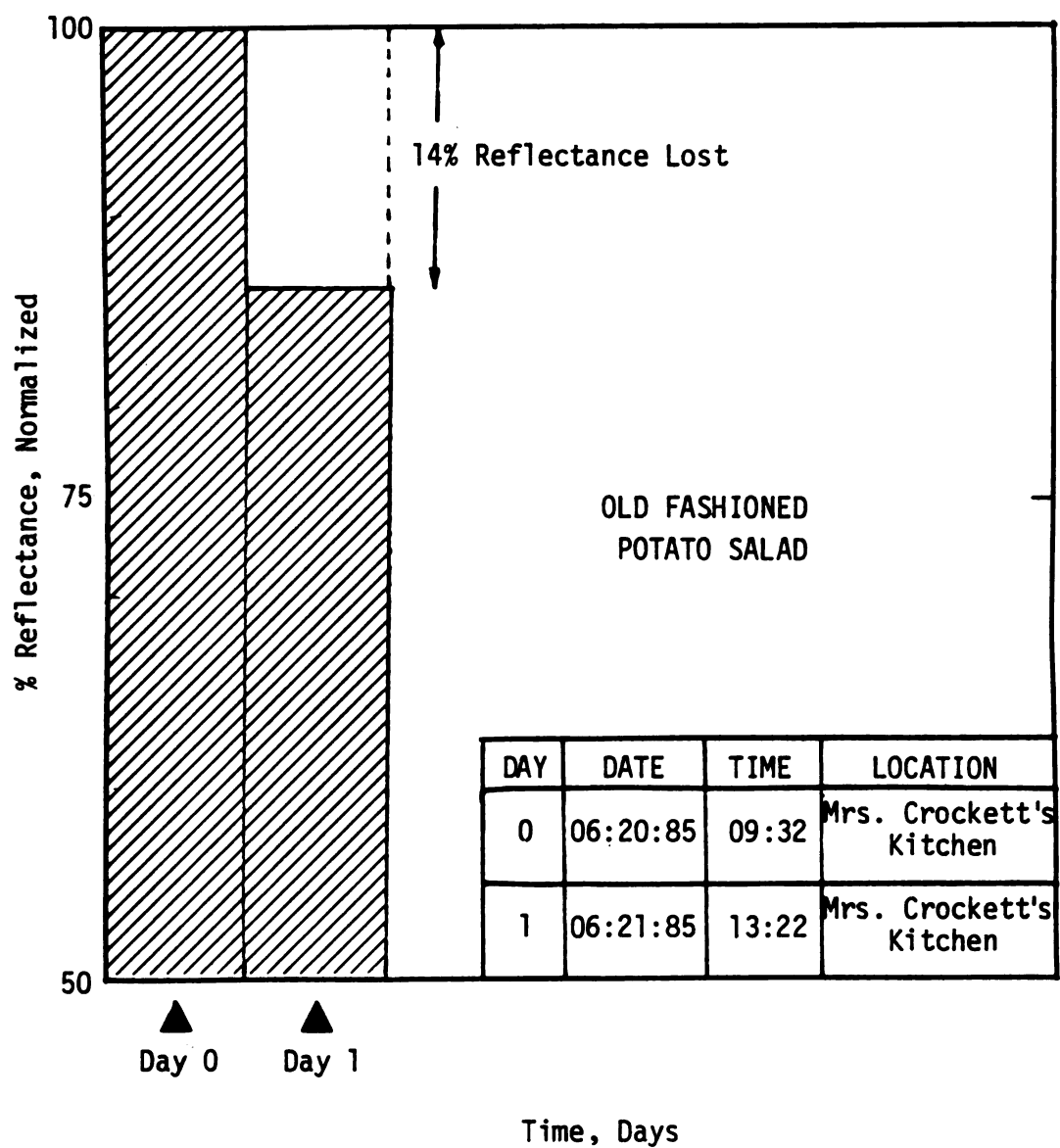


Figure 18. Loss of Reflectance for One Salad Variety After One Day Storage.

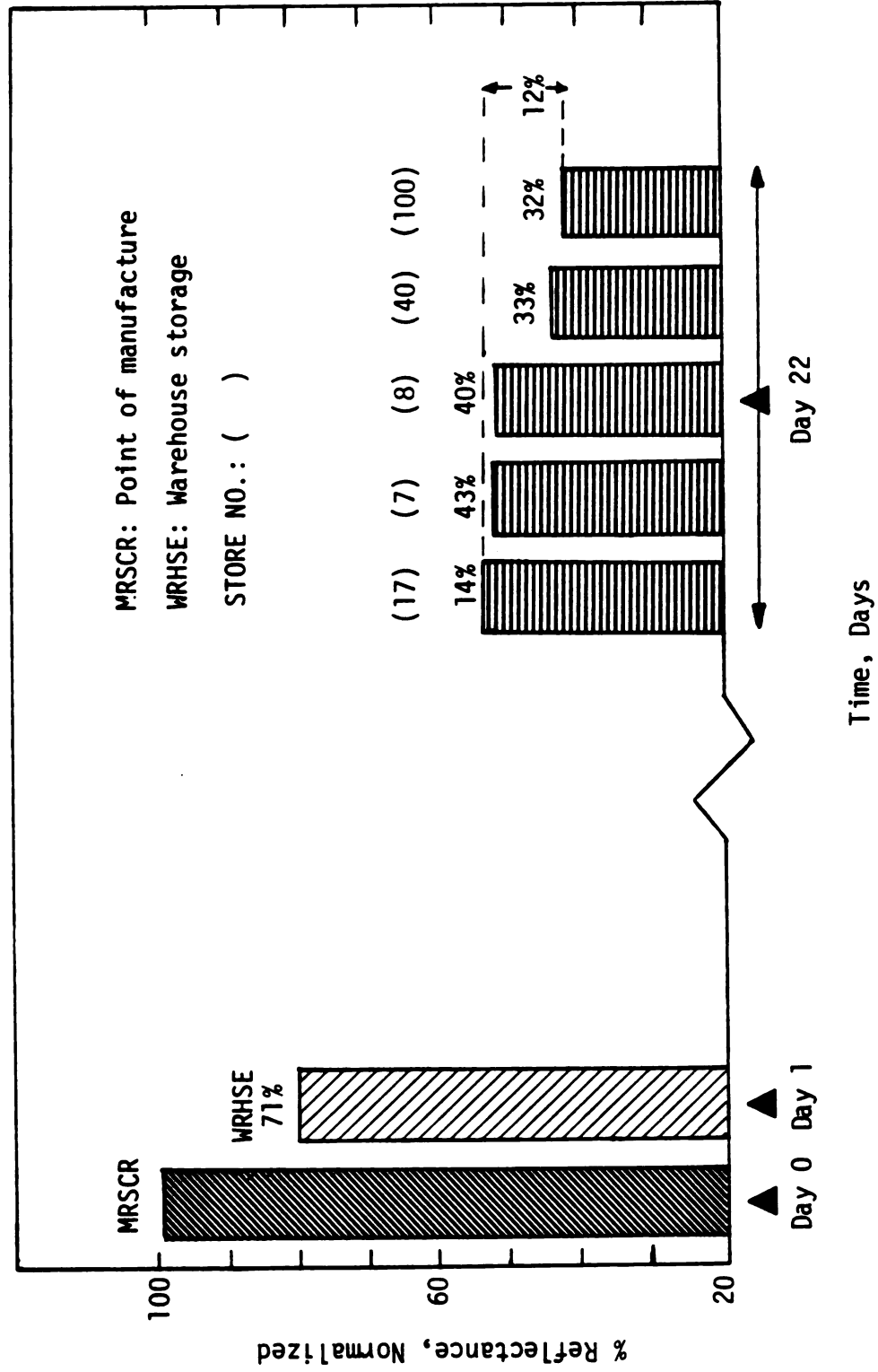


Figure 19. Comparison of Reflectance Values for Samples of One Product Lot Retrieved from Different Locations.

CONCLUSIONS

1. The "LifeLines" indicator Time-Temperature Integrating Polymer (TTIP) performed reliably with respect to first order kinetics over the range of time and temperatures encountered in the study.

a. Variance of mean scans for two Material Codes (57 and 61) tested under controlled conditions was not significantly affected by level (%) of Reflectance over the range of reflectance values observed.

b. The difference between high and low values of % Reflectance for an individual indicator scanned consecutively at a given time is relatively constant regardless of actual reflectance value, and is within a range of 7 to 12 units for % Reflectance of 81 to 18.

c. Linear regression analysis of Material Code vs. storage temperature yielded observed values for reaction rate (k) and activation energy (E_a) within 4% and 20%, respectively, of those reported by the manufacturer.

2. Quality parameters of salads which are sensitive to thermal history and significant in evaluating remaining shelf life include overall flavor and chlorophyll color.

3. Sensory flavor scores and color of certain green vegetables in salads were correlated with % Reflectance of the TTIPs.

a. Mean sensory flavor scores of six salad varieties were positively correlated with % Reflectance. As % Reflectance decreased, flavor scores decreased. While a significant relationship between

salad age and flavor score was established, storage temperature was not significantly related to score.

b. Degradation of chlorophyll in green peppers of five salad varieties was exponentially correlated with % Reflectance.

4. The "LifeLines" TTIP has been shown to be useful in identifying areas of thermal abuse in the distribution channel.

APPENDICES

APPENDIX I

Typical Data Collection Sheet for Lab Study on Physical
Condition of Salads

Date	5-11-85	Storage Temp.	7.2°C
<u>Salad</u>	<u>Syneresis</u>	<u>Separation</u>	<u>Surface</u>
CSA	-	+	Excess dressing
Odor	Mild		
Color	Dull, bland		
Comments			
HCCS	+	-	Tiny gas bubbles
Odor	Very 'cheesey'		
Color	Slightly dull		
Comments	Pieces cling to cap; dressing shrunk		
HCS	-	-	Flat and smooth
Odor	Mild, slightly tart, vinegary		
Color	Bright, good definition		
Comments	Dressing looks good; smooth and creamy		
IPS	-	+	Surface looks dry
Odor	Mild, tart		
Color	Dull		
Comments			

OFPS	_____	_____ + _____ - _____	Dressing shrunk
Odor	Mild, egg-y		
Color	OK, green pepper bright		
Comments	One potato piece with bruise		

APPENDIX II

Baseline Values for Field Study

Salad	Lot	Material Code	Package	Baseline
CSA	1	63	shipper	80
HCCS	1	63	shipper	81
HCS	1	63	shipper	73
IPS	1	63	shipper	74
OFPS	1	63	shipper	74
SMS	1	63	shipper	73
SPS	1	63	shipper	78
TDFS	1	63	shipper	77
CSA	1	63	sleeve	60/74*
HCCS	1	63	sleeve	58/62
HCS	1	63	sleeve	70
IPS	1	63	sleeve	70
OFPS	1	63	sleeve	63/73
SMS	1	63	sleeve	60/70
SPS	1	63	sleeve	61
TDFS	1	63	sleeve	58

CSA	2	65	shipper	80
HCCS	2	65	shipper	77
HCS	2	65	shipper	80
IPS	2	65	shipper	74
OFPS	2	65	shipper	76
SMS	2	65	shipper	80
SPS	2	65	shipper	76
VGS	2	65	shipper	77

CSA	2	65	sleeve	79
HCCS	2	65	sleeve	75
HCS	2	65	sleeve	72/75
IPS	2	65	sleeve	72
OFPS	2	65	sleeve	79
SMS	2	65	sleeve	75
SPS	2	65	sleeve	72
VGS	2	65	sleeve	76

CSA	3	65	shipper	79
HCCS	3	65	shipper	78
HCS	3	65	shipper	73
IPS	3	65	shipper	72
OFPS	3	65	shipper	72
SMS	3	65	shipper	74
SPS	3	65	shipper	78
TDFS	3	65	shipper	76
VGS	3	65	shipper	78

CSA	3	65	sleeve	75
HCCS	3	65	sleeve	74
HCS	3	65	sleeve	71
IPS	3	65	sleeve	71
OFPS	3	65	sleeve	75
SMS	3	65	sleeve	72
SPS	3	65	sleeve	72
TDFS	3	65	sleeve	72
VGS	3	65	sleeve	75

*Indicates two different baselines due to sequence of indicators used.

APPENDIX III

Procedure for Color Analysis of Green Vegetable
Salad Components

General Procedure

1. Empty salads of one variety from containers into a colander. Run tap water over salads until dressing is removed; allow water to drain.
2. Sift through salad and remove broccoli, celery, or peppers.
3. Weigh out approximately 18-20 grams of broccoli, etc.
4. Rinse off samples with tap water and gently blot dry with paper towel.
5. Place weighed sample in disposable opaque plastic container. Clear containers may be used if wrapped in aluminum foil prior to storage.
6. If samples are not to be analyzed immediately, store at 0°C.
7. Samples must be thawed at least 15 minutes prior to analysis.

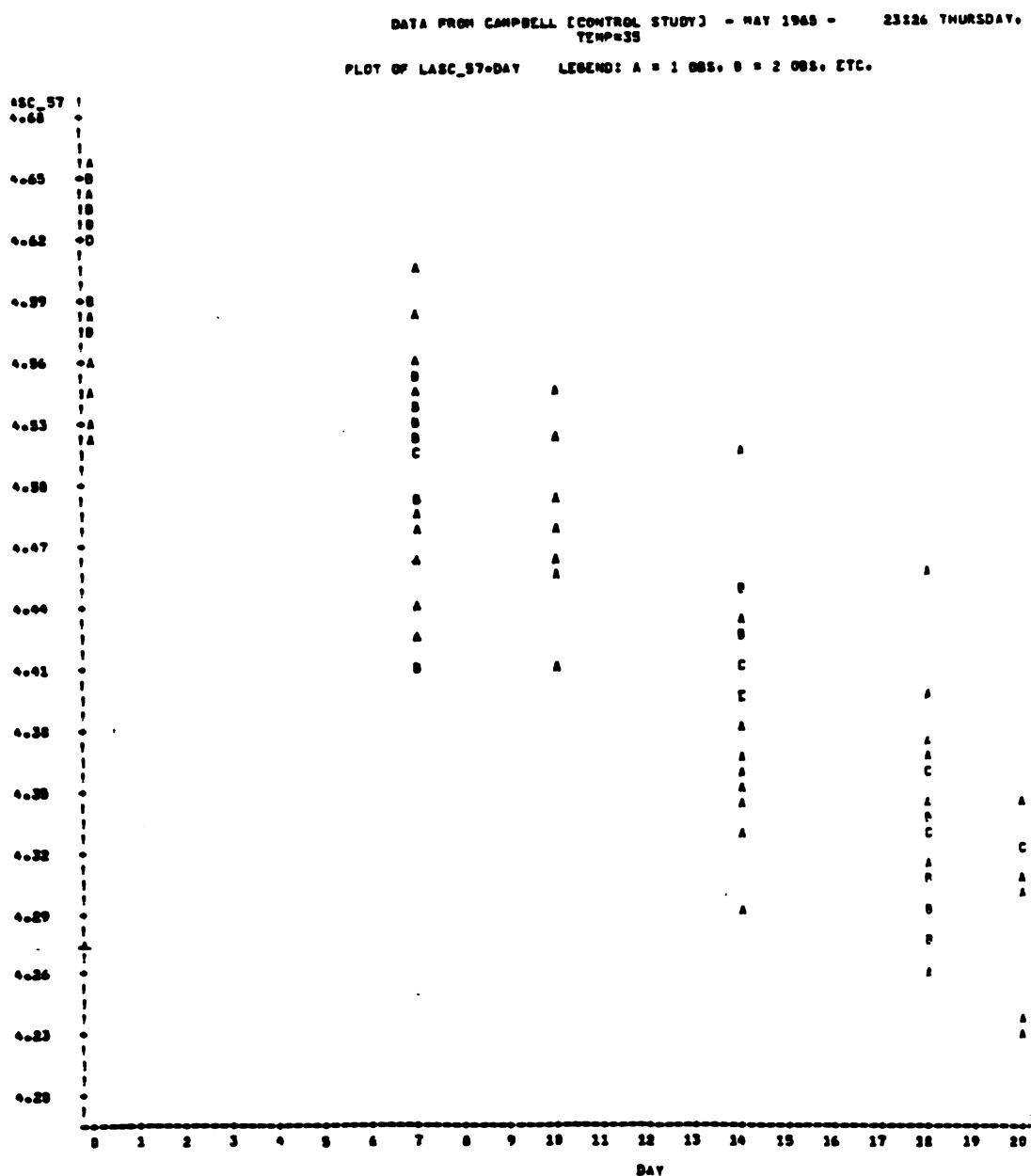
Broccoli

1. Grind broccoli in food processor until both the stem and flower portions are less than 1 mm in diameter.
2. Weigh out 5 grams into each of 3 clean, dry test tubes.
3. Add 10 ml anhydrous ethyl ether. Stir, using a pipette to suspend sample. Cork each tube with cotton to prevent evaporation of ether.
4. Extract for 5 minutes.

5. Draw off supernatant with a pipette and place in cuvette.
6. Scan each sample under spectrum of 300 to 700 nm.

Celery and Green Pepper

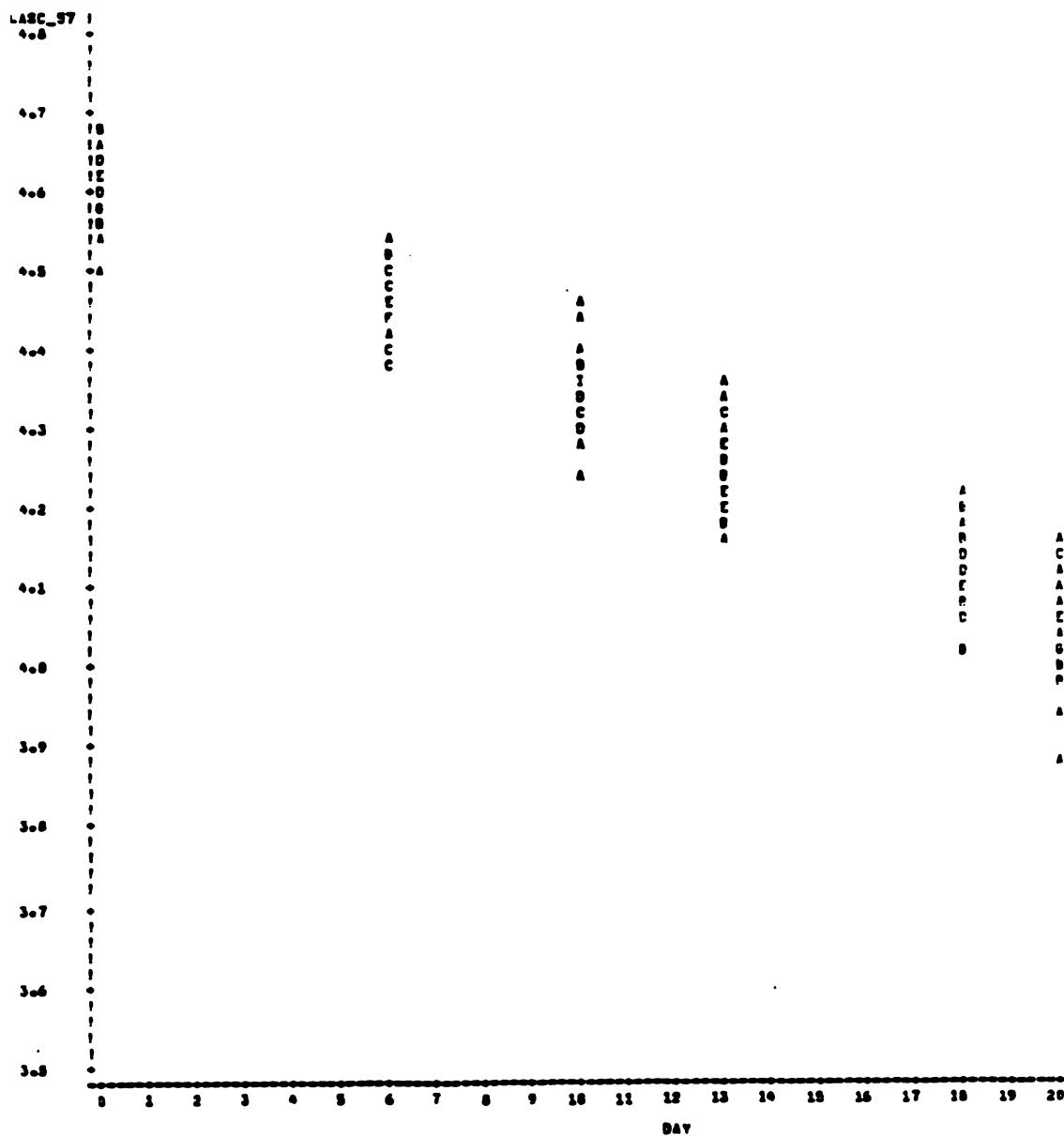
1. Place sample into mortar and grind well with pestle, leaving only the skins intact.
2. Weigh out 5 grams of the homogenate into each of 3 clean, dry test tubes. There should be approximately 4 grams of skins to each 1 gram of liquid.
3. Add 5 ml anhydrous ethyl ether to each test tube. Stir, and cork each tube to prevent evaporation of the solvent.
4. Extract celery and pepper samples for 5 and 2 minutes respectively.
5. Remove the supernatant with a pipette and place in cuvette.
6. Scan the sample under a spectrum of 300 to 700 nm.



Appendix Figure IVa. Plot of Mean Reflectance Values of Individual Indicators of Material Code 57 at 1.7°C Storage vs. Time.

DATA FROM CAMPBELL [CONTROL STUDY] - MAY 1968 - 23126 THURSDAY,
TEMP=4.5

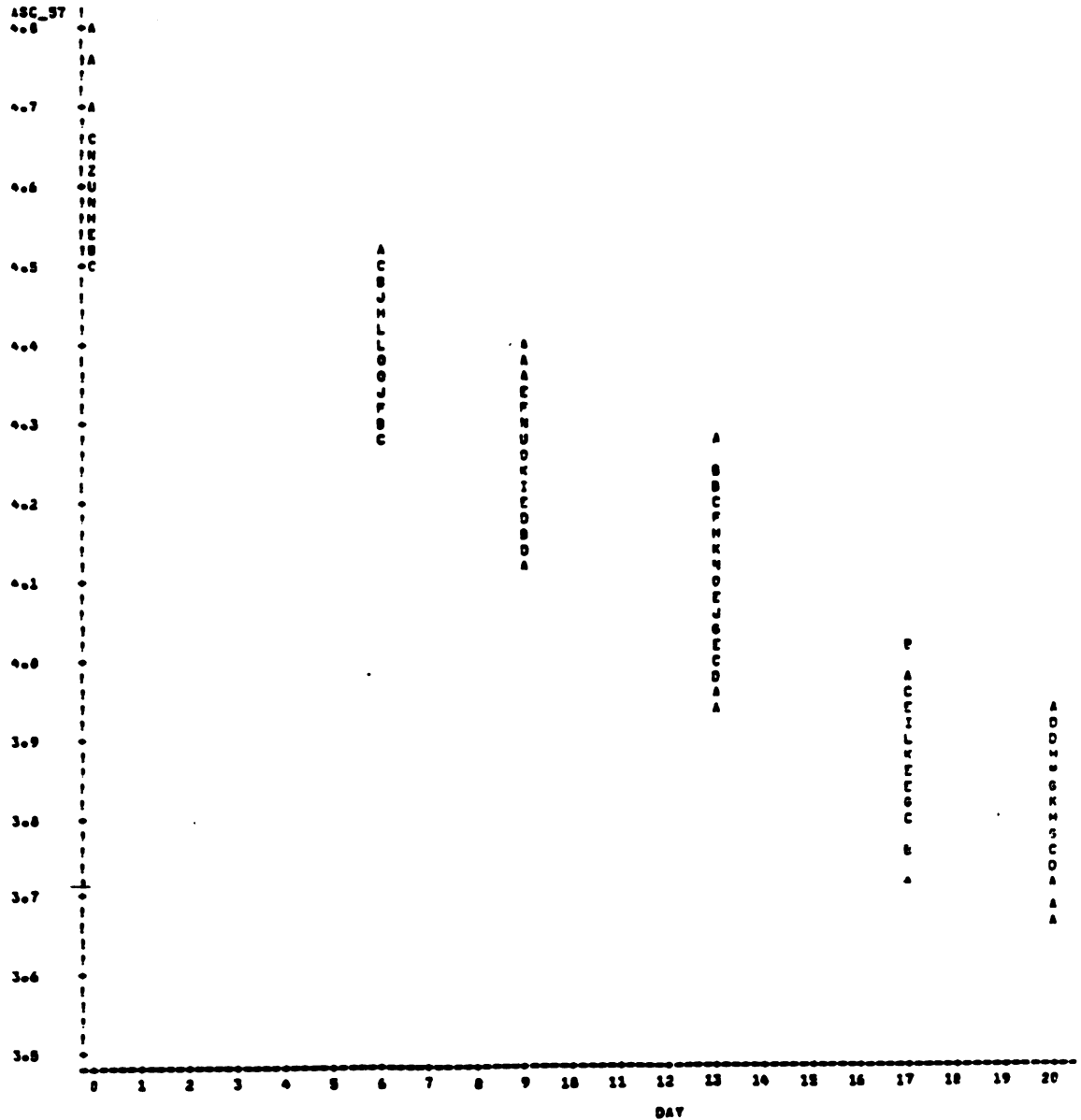
PLOT OF LASC_57=DAY LEGEND: A = 1 OBS, B = 2 OBS, ETC.



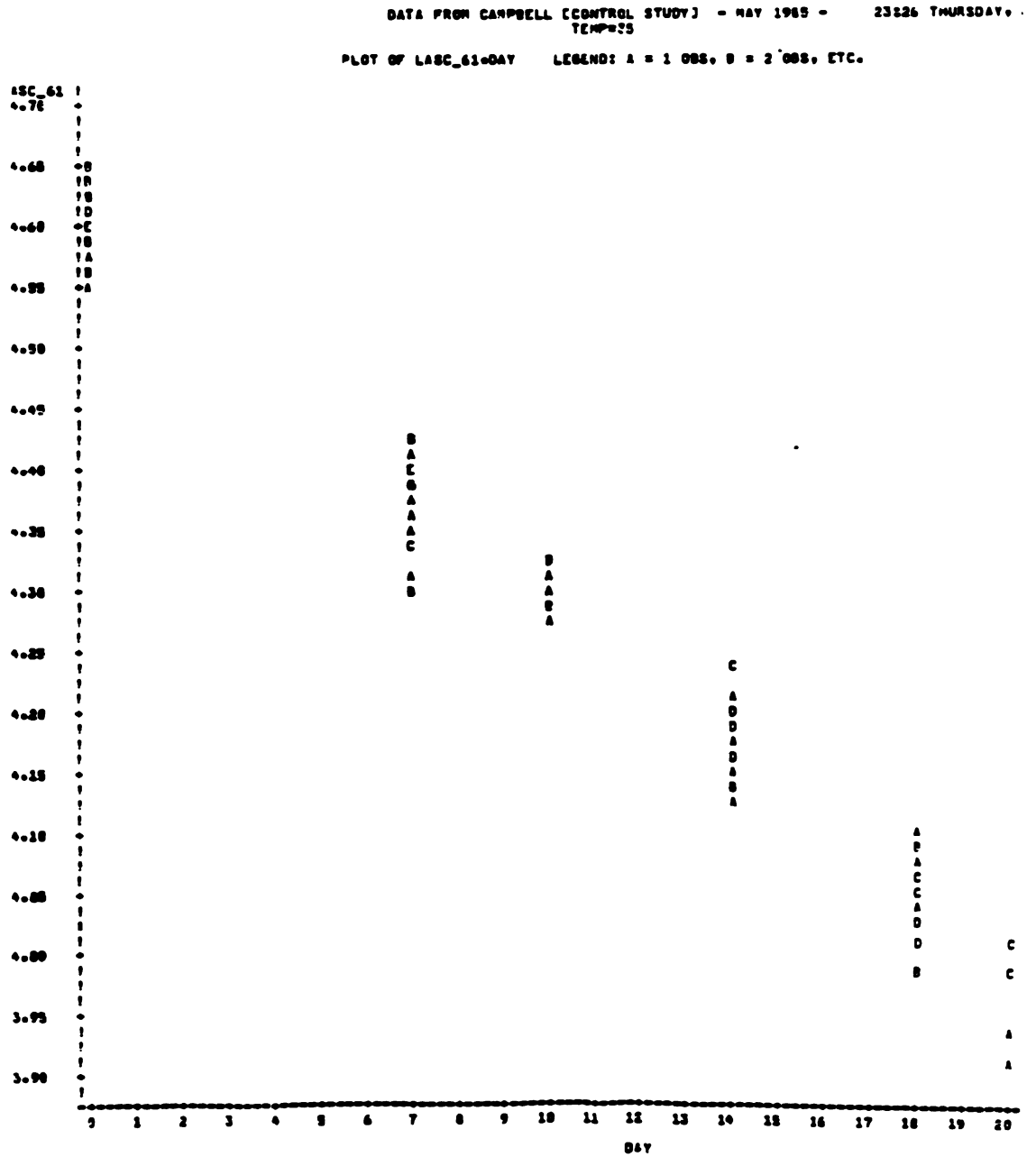
Appendix Figure IVb. Plot of Mean Reflectance Values of Individual Indicators of Material Code 57 at 4.5°C Storage vs. Time.

DATA FROM CAMPBELL [CONTROL STUDY] - MAY 1965 - 23126 THURSDAY, JI
TEMP=05

PLOT OF LASC_57=DAY LEGEND: A = 1 OBS, B = 2 OBS, ETC.

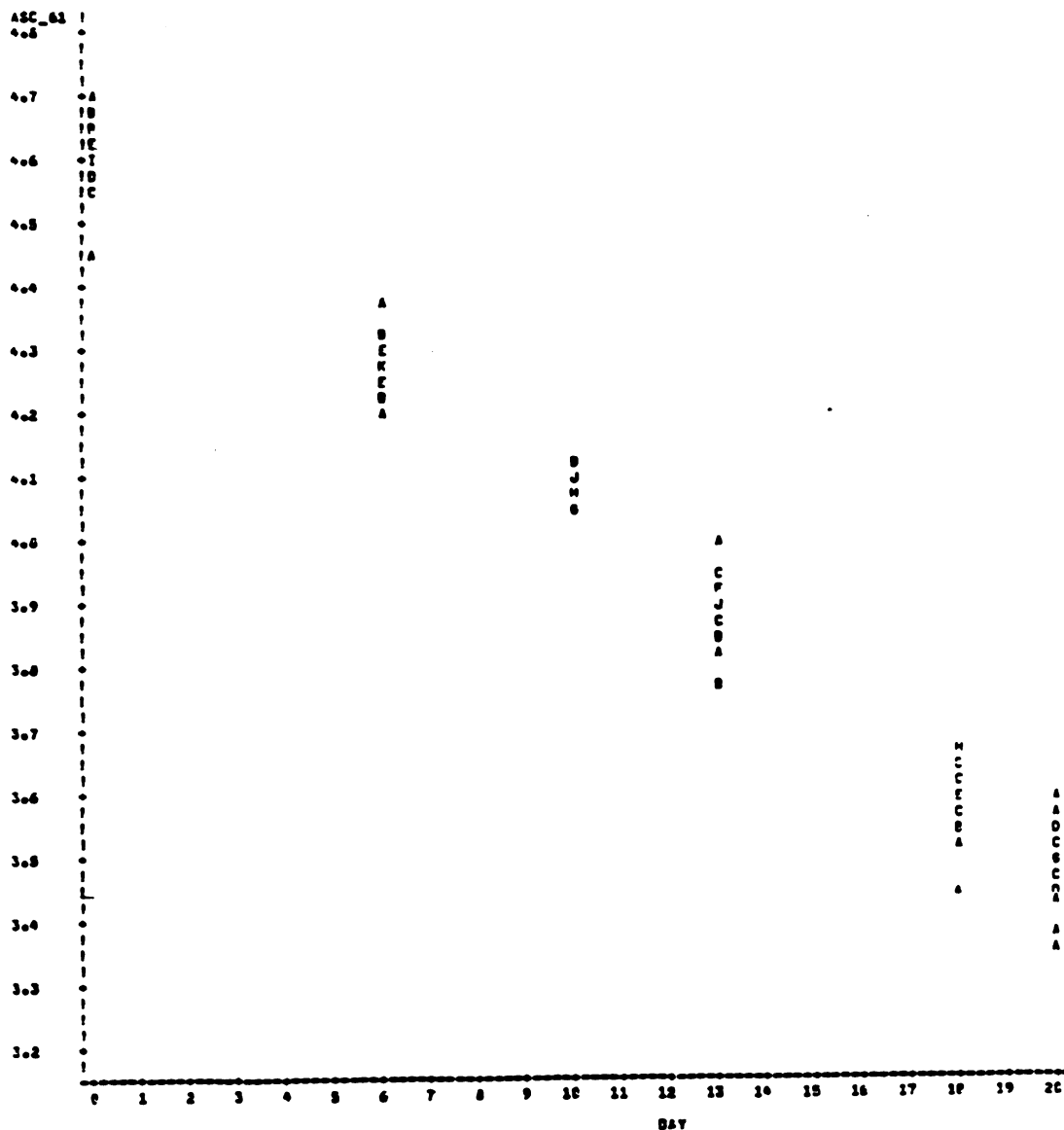


Appendix Figure IVc. Plot of Mean Reflectance Values of Individual Indicators of Material Code 57 at 7.2°C Storage vs. Time.

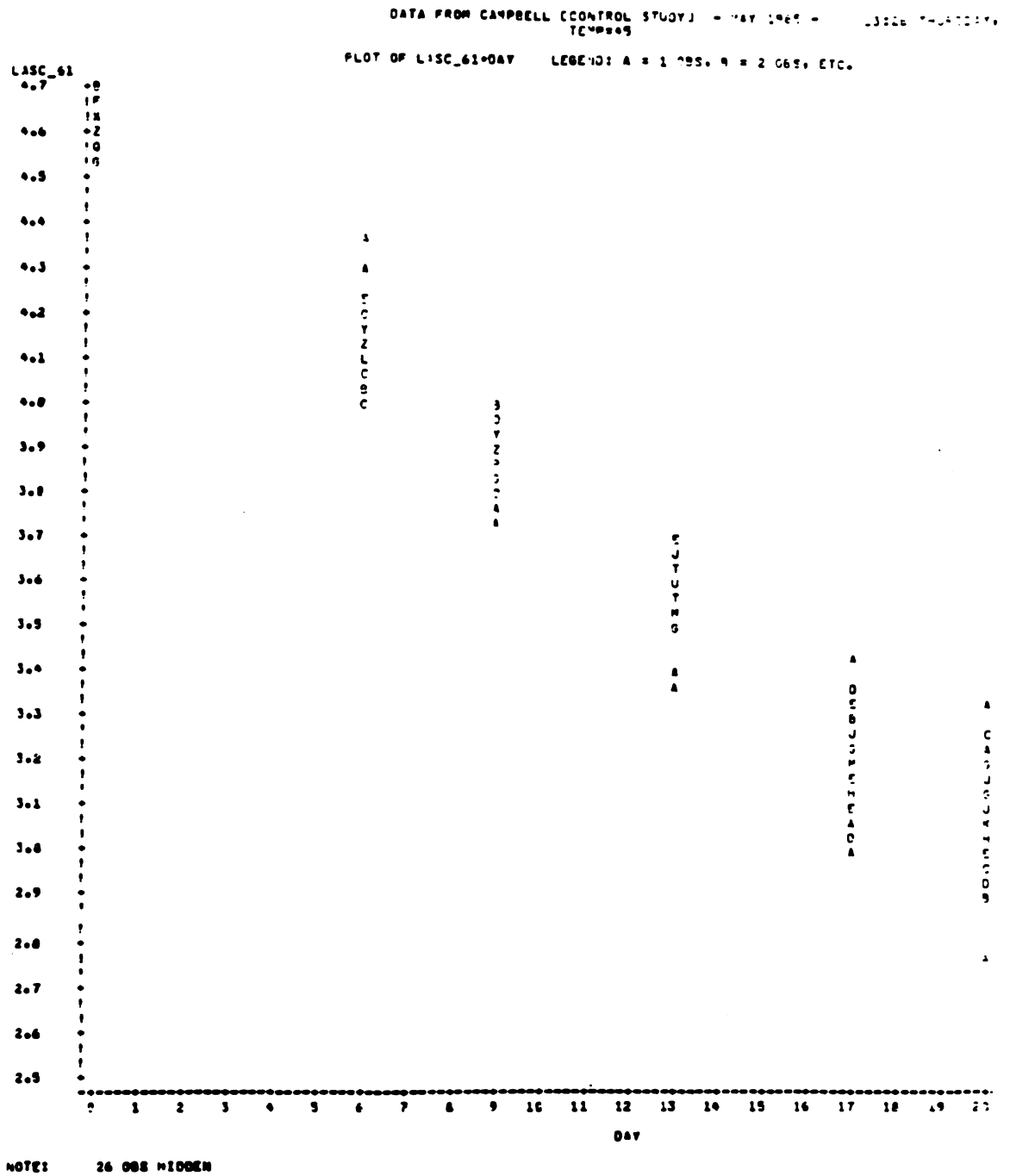


DATA FROM CAMPBELL [CONTROL STUDY] - MAY 1985 - 23:26 THURSDAY.
TEMP=40

PLOT OF LASC_61-DAY LEGEND: A = 1 OBS., B = 2 OBS., ETC.



Appendix Figure IVe. Plot of Mean Reflectance Values of Individual Indicators of Material Code 61 at 4.5°C Storage Vs. Time.



Appendix Figure IVf. Plot of Mean Reflectance Values of Individual Indicators of Material Code 61 at 7.2°C Storage vs. Time.

APPENDIX V

Occurrence of Syneresis and of Separation in Salads

Syneresis is defined as leakage of water from the salad or dressing. Separation is the breakdown of emulsion in the salad dressing.

- indicates no evidence

/ indicates slight evidence

+ indicates definite evidence

Scoring: (-) = 0; (/) = 0.5; (+) = 1.0

* indicates observations past code date

Chicken Salad with Almonds

Date	Day	<u>Syneresis</u>			<u>Separation</u>		
		1.7°C	4.5°C	7.2°C	1.7°C	4.5°C	7.2°C
4-24	5	-			-		
4-26	6		-	-		-	-
5-1	12	-	/	-	-	+	-
5-8	19		-	+		+	/
5-9	20	-			-		
5-12	23	-	-	-	-	-	+
5-15	26*	-	+	-	/	-	-
5-12	30*	/	-	-	-	-	-
5-22	33*	-	-	-	-	-	-
Score		0.5	1.5	1.0	0.5	2.0	1.5

Ham and Cheddar Cheese Salad

Date	Day	<u>Syneresis</u>			<u>Separation</u>		
		1.7°C	4.5°C	7.2°C	1.7°C	4.5°C	7.2°C
4-24	5	-			-		
4-26	7		-	-		-	-
5-1	12	-	-	/	-	-	-
5-8	19		-	/		-	-
5-9	20	0			-		
5-12	23	0	-	+	-	-	-
5-15	26*	0	-	+	-	-	/
5-19	30*		/	+		-	-
5-22	33*	+	+	+	-	-	-
Score		1.0	1.5	5.0	0	0	0.5

Holiday Cole Slaw

Date	Day	<u>Syneresis</u>			<u>Separation</u>		
		1.7°C	4.5°C	7.2°C	1.7°C	4.5°C	7.2°C
4-24	6	-			-		
4-26	8		-	-		-	-
5-1	13	-	-	-	-	-	-
5-8	20		-	-		-	-
5-9	21	-			-		
5-12	24*	-	-	-	-	-	-
5-15	27*	-	-	-	-	-	-
5-19	31*	-	-	-	-	-	-
5-22	34*	-	-	-	-	-	-
Score		0	0	0	0	0	0

Italian Pasta Salad

Date	Day	<u>Syneresis</u>			<u>Separation</u>		
		1.7 ⁰ C	4.5 ⁰ C	7.2 ⁰ C	1.7 ⁰ C	4.5 ⁰ C	7.2 ⁰ C
4-24	6	-			-		
4-26	8		-	-		-	-
5-1	13	-	-	-	-	-	-
5-8	20		-	+		-	+
5-9	21	-			-		
5-12	24*	-	-	+	-	-	+
5-15	27*	-	-	-	/	/	+
5-19	31*	-	-	-	+	+	+
5-22	34*	-	-	-	-	-	+
Score		0	0	2.0	1.5	1.5	5.0

Old Fashioned Potato Salad

Date	Day	<u>Syneresis</u>			<u>Separation</u>		
		1.7 ⁰ C	4.5 ⁰ C	7.2 ⁰ C	1.7 ⁰ C	4.5 ⁰ C	7.2 ⁰ C
4-24	6	-			-		
4-26	8		-	-		-	-
5-1	13	-	/	-	-	/	+
5-8	20		-	-		-	-
5-9	21	-			-		
5-12	24*	+	-	+	-	-	-
5-15	27*	-	-	/	-	-	+
5-19	31*	-	-	-	-	-	-
5-22	34*	+	-	+	-	-	-
Score		2.0	0.5	2.5	0	0.5	2.0

Seashell Macaroni Salad

Date	Day	<u>Syneresis</u>			<u>Separation</u>		
		1.7 ⁰ C	4.5 ⁰ C	7.2 ⁰ C	1.7 ⁰ C	4.5 ⁰ C	7.2 ⁰ C
4-24	6	-			-		
4-26	8		-	-		+	+
5-1	13	/	/	-	-	-	+
5-8	20	-	-	-	/	+	+
5-12	24*	+	+	+	+	-	+
5-15	27*	-	+	+	/	+	+
5-19	31*	/	+	+	-	-	-
5-22	34*	+	+	+	+	+	+
Score		3.0	4.5	4.0	3.0	4.0	6.0

Seafood Pasta Salad

Date	Day	<u>Syneresis</u>			<u>Separation</u>		
		1.7 ⁰ C	4.5 ⁰ C	7.2 ⁰ C	1.7 ⁰ C	4.5 ⁰ C	7.2 ⁰ C
4-24	5	-			-		
4-26	7		-	-		-	+
5-1	12	-	-	-	/	+	+
5-8	19	-	-	+	/	-	-
5-12	23	+	+	+	+	-	-
5-15	26*	+	-	-	-	+	+
5-19	30*	-	+	+	-	-	-
5-22	33*	+	+	+	-	/	/
Score		3.0	3.0	4.0	2.0	2.5	3.5

Tropical Delight Fruit Salad

Date	Day	<u>Syneresis</u>			<u>Separation</u>		
		1.7°C	4.5°C	7.2°C	1.7°C	4.5°C	7.2°C
4-24	5	-			-		
4-26	7		-	-		-	-
5-1	12	-	-	-	-	-	-
5-8	19	-	-	-	-	-	-
5-12	23	-	-	-	-	-	-
5-15	26*	-	-	+	-	-	+
5-19	30*	-	-	+	-	-	+
5-22	33*	+	-	+	-	-	+
Score		1.0	0	3.0	0	0	3.0

Vegetable Garden Salad

		<u>Syneresis</u>			<u>Separation</u>		
4-24	6	-			-		
4-26	8		-	-		-	-
5-1	13	-	-	+	/	-	-
5-8	20	-	-	-	-	-	-
5-12	24*	-	-	-	-	-	
5-15	27*	-	-	+	-	-	+
5-19	31*	-	-	-	-	-	-
5-22	34*	-	-	/	-	-	-
Score		0	0	2.5	0.5	0	1.0

APPENDIX VI

Observation of Salad Color During Shelf Life

Salads were observed for overall color during shelf life. All observations were done by the same person, in the same location (Microbiology Lab, 227 Food Science), and under similar lighting conditions. Color descriptions were defined as follows:

bland: neutral, beige color, nondistinct

brt, gd df: bright, good definition, colors of different salad components distinct from each other

dull: lacking brightness

sl dull: slightly dull

<u>Chicken Salad with Almonds</u>				
Date	Day	1.7°C	4.5°C	7.2°C
4-24	5	bland		
4-26	7		bland	bland
5-1	12	bland	bland	bland
5-8	19		bland	bland
5-9	20	bland		
5-11	22			dull
5-12	23	dull	dull	
5-15	26	bland	bland	dull
5-19	30	dull	dull	dull
5-22	33	dull	bland	dull

Ham and Cheddar Cheese Salad

Date	Day	1.7°C	4.5°C	7.2°C
4-24	5	gd defn		
4-26	7		brt, gd df	brt, gd df
5-1	12	brt, gd df	brt, gd df	brt, gd df
5-8	19		sl dull	sl dull
5-9	20	brt		
5-11	22			dull
5-12	23	sl dull	sl dull	
5-15	26	sl dull	sl dull	sl dull
5-19	30		dull	dull
5-22	33	dull	dull	dull

Holiday Cole Slaw

Date	Day	1.7°C	4.5°C	7.2°C
4-24	6	brt		
4-26	8		brt, gd df	brt, gd df
5-1	13	brt, gd df	brt, gd df	brt, gd df
5-8	20		brt	brt
5-9	21	brt, gd df		
5-11	23			brt, gd df
5-12	24	sl dull	sl dull	
5-15	27	sl dull	sl dull	sl dull
5-19	31	sl dull	dull	dull
5-22	34	dull	dull	dull

Italian Pasta Salad

Date	Day	1.7°C	4.5°C	7.2°C
4-24	6	brt, gd df		
4-26	8		brt, gd df	brt, gd df
5-1	13	brt, gd df	brt, gd df	brt, gd df
5-8	20		brt, gd df	sl dull
5-9	21	brt, gd df		
5-11	23			dull
5-12	24	dull	sl dull	
5-15	27	dull	sl dull	sl dull
5-19	31	dull	dull	dull
5-22	34	dull	sl dull	dull

Old Fashioned Potato Salad

Date	Day	1.7°C	4.5°C	7.2°C
4-24	6	brt, gd df		
4-26	8		brt, gd df	brt, gd df
5-1	13	brt	brt	
5-8	20		brt	brt
5-9	21	brt		
5-11	23			brt
5-12	24	brt	sl dull	
5-15	27	brt	brt	brt
5-19	31	brt	brt	brt
5-22	34		brt	brt

Seashell Macaroni Salad

Date	Day	1.7°C	4.5°C	7.2°C
4-24	6	brt, gd df		
4-26	8		brt, gd df	brt, gd df
5-1	13	brt, gd df	brt, gd df	brt, gd df
5-8	20		brt, gd df	brt, gd df
5-9	21	brt, gd df		
5-11	23			sl dull
5-12	24	brt	sl dull	
5-15	27	sl dull	sl dull	sl dull
5-19	31	sl dull	sl dull	dull
5-22	34	dull	dull	dull

Seafood Pasta Salad

Date	Day	1.7°C	4.5°C	7.2°C
4-24	5	brt, gd df		
4-26	7		brt, gd df	brt, gd df
5-1	12	brt, gd df	brt, gd df	brt, gd df
5-8	19		brt, gd df	brt, gd df
5-9	20	brt		
5-11	22			sl dull
5-12	23	sl dull	sl dull	
5-15	26	sl dull	sl dull	sl dull
5-19	30	brt	sl dull	sl dull
5-22	33	brt	dull	dull

Tropical Delight Fruit Salad

Date	Day	1.7°C	4.5°C	7.2°C
4-24	5	brt, gd df		
4-26	7		brt, gd df	brt, gd df
5-1	12	brt, gd df	brt, gd df	brt, gd df
5-8	19		brt, gd df	brt, gd df
5-9	20	sl dull		
5-11	22			sl dull
5-12	23	sl dull	sl dull	
5-15	26	sl dull	sl dull	dull
5-19	30		sl dull	dull
5-22	33	sl dull	sl dull	dull

Vegetable Garden Salad

Date	Day	1.7°C	4.5°C	7.2°C
4-24	6	brt, gd df		
4-26	8		brt, gd df	brt, gd df
5-1	13	brt, gd df	brt, gd df	brt, gd df
5-8	20		brt	brt
5-9	21	brt		
5-11	23			sl dull
5-12	24	brt	sl dull	
5-15	27	brt	sl dull	sl dull
5-19	31	brt	sl dull	sl dull
5-22	34	sl dull	dull	dull

APPENDIX VII

Microbiological Data from Lab Study

Day	Chicken with Almonds Salad			Ham and Cheddar Cheese Salad		
	Total Plate Count			Total Plate Count		
	1.7°C	4.5°C	7.2°C	1.7°C	4.5°C	7.2°C
5	1.0x10 ⁴			4.2x10 ⁴		
7		7.7x10 ³	3.6x10 ³		2.7x10 ⁴	1.1x10 ³
12	4.8x10 ³	2.7x10 ³	1.3x10 ⁴	3.9x10 ³	3.0x10 ⁴	2.6x10 ⁴
19		1.9x10 ³	5.0x10 ³		3.3x10 ⁴	1.4x10 ⁴
20	3.2x10 ³			1.3x10 ⁴		
23		7.7x10 ³	5.0x10 ³	2.9x10 ⁴	1.5x10 ⁴	6.2x10 ⁴
26	1.9x10 ³	2.2x10 ³	6.1x10 ³	3.5x10 ⁴	2.9x10 ⁴	2.6x10 ⁴
33	2.9x10 ³	3.8x10 ³	6.4x10 ³	4.8x10 ⁴	3.0x10 ⁴	2.0x10 ³

Day	Holiday Cole Slaw			Italian Pasta Salad		
	1.7°C	4.5°C	7.2°C	1.7°C	4.5°C	7.2°C
6	6.5x10 ³			2.3x10 ³		
8		2.2x10 ³	1.7x10 ³		5.6x10 ²	9.5x10 ²
13	8.8x10 ²	1.1x10 ⁴	9.4x10 ²	9.5x10 ²	1.2x10 ³	8.2x10 ²
20		1.2x10 ³	7.4x10 ²		6.7x10 ²	1.9x10 ⁴
21	2.0x10 ⁴			3.0x10 ²		
24	6.7x10 ⁴	5.2x10 ²	1.2x10 ³	3.2x10 ³	4.4x10 ⁴	4.1x10 ³
27	4.8x10 ⁴	3.1x10 ²	6.6x10 ²		4.2x10 ²	8.6x10 ³
34	3.4x10 ²	7.7x10 ²	6.1x10 ²	3.8x10 ²	2.8x10 ³	1.1x10 ⁴

Day	<u>Old Fashioned Potato Salad</u>			<u>Seashell Macaroni Salad</u>		
	Total Plate Count			Total Plate Count		
	1.7°C	4.5°C	7.2°C	1.7°C	4.5°C	7.2°C
6	2.7x10 ³			2.4x10 ³		
8		7.9x10 ²	1.6x10 ³		1.2x10 ³	6.5x10 ²
13	3.8x10 ⁴	1.2x10 ³	9.6x10 ²	1.0x10 ³	1.4x10 ³	5.8x10 ²
20		6.5x10 ²	4.7x10 ²		1.0x10 ³	9.3x10 ²
21	5.9x10 ²			1.2x10 ³		
24	7.6x10 ²	8.8x10 ³	8.3x10 ²	8.7x10 ⁴	1.0x10 ³	4.2x10 ²
27	4.7x10 ²	7.4x10 ²	8.2x10 ²	7.8x10 ²	6.2x10 ³	1.4x10 ³
34	1.9x10 ³	5.2x10 ²	1.8x10 ³	8.0x10 ²	4.6x10 ²	9.3x10 ²

Day	<u>Seafood Pasta Salad</u>			<u>Tropical Delight Fruit Salad</u>		
	Total Plate Count			Total Plate Count		
	1.7°C	4.5°C	7.2°C	1.7°C	4.5°C	7.2°C
5	8.1x10 ³			1.3x10 ²		
7		7.2x10 ³			6.0x10 ¹	3.0x10 ¹
12	5.4x10 ³	8.6x10 ³	8.8x10 ³	9.0x10 ¹	7.0x10 ¹	5.0x10 ¹
19		3.6x10 ³	2.5x10 ⁴		2.0x10 ¹	1.0x10 ¹
20	1.2x10 ³			1.5x10 ¹		
23	3.5x10 ⁴	1.1x10 ⁴	1.6x10 ⁴	7.4x10 ²	2.8x10 ⁴	9.5x10 ¹
26	3.6x10 ⁴	7.2x10 ³	7.4x10 ³	1.2x10 ²	2.0x10 ¹	1.3x10 ²
33	4.6x10 ³	1.1x10 ⁵	1.0x10 ⁴	5.5x10 ¹	5.4x10 ³	3.0x10 ²

Vegetable Garden Salad

Day	Total Count Plate		
	1.7°C	4.5°C	7.2°C
5	6.0×10^2		
7		5.9×10^2	
12	5.7×10^2	5.0×10^2	3.3×10^2
19		1.2×10^2	2.8×10^2
20	3.6×10^2		
23	2.2×10^2	4.2×10^2	2.0×10^2
26	2.4×10^2	6.0×10^2	8.1×10^2
33	2.6×10^2	2.1×10^3	2.2×10^2

Chicken with Almonds Salad

Day	Psychrotrophic Count			Yeast and Mold Count		
	1.7°C	4.5°C	7.2°C	1.7°C	4.5°C	7.2°C
5	10	<10	<10			
7	<10	<10	<10			
12	<10	20	<10	30	<10	0
21			<10	10	30	0
23	<10	30	30	<10	<10	<10
26	20	<10	30	<10	<10	<10
33	20	<10	<10	<10	110	80

Ham and Cheddar Cheese Salad

5	280	10	90			
7	25	<10	120			
12	<10	20	10	20	10	30
21			260	30	10	30
23	180	80		20	12	90
26	250	11	300	<10	15	85
33	40	1300	1300	30	14	<10

Holiday Cole Slaw

6	200	200	14			
8	<10	150	100			
13	<10	<10	<10	10	<10	<10
22			380	10	<10	<10
24	100	120		<10	<10	10
27	10	100	280	30	<10	50
34	<10	<10	<10	<10	23	<10

Italian Pasta Salad

Day	Psychrotrophic Count			Yeast and Mold Count		
	1.7°C	4.5°C	7.2°C	1.7°C	4.5°C	7.2°C
6	260	30	10			
8	<10	10	100			
13	60	<10	1500	10	0	<10
22			4400	<10	0	2300
24	95	21		0	0	70
27	30	70	470	0	0	4800
34	<10	3400	4200	0	0	1900

Old Fashioned Potato Salad

6	140	190	240			
8	20	25	300			
13	280	<10	<10	<10	<10	<10
22			240	<10	<10	<10
24	280	120		10	<10	<10
27	10	280	310	<10	<10	<10
34	800	<10	340	<10	<10	<10

Seashell Macaroni Salad

6	950	300	320			
8	1000		130			
13	600	<10	<10	0	0	0
22			20		0	0
24	100	30		0	0	<10
27	30	10	200	0	<10	<10
34	30	300	<10	0	<10	<10

Seafood Pasta Salad

Day	Psychrotrophic Count			Yeast and Mold Count		
	1.7°C	4.5°C	7.2°C	1.7°C	4.5°C	7.2°C
5	260	120	110			
7	10	<10	10			
12	<10	20	85	<10	<10	0
21			40	<10	<10	0
23	70	75		10	15	0
26	60	130	760	<10	<10	0
33	<10	710	<10	10	20	0

Tropical Delight Fruit Salad

5	6800	490	2800			
7	4800	1900	270			
12	<10	290	160	790	10	670
21			370	220	20	60
23	290	40		30	<10	30
26	630	470	100	<10	15	20
33	90	50	50	<10	<10	130

APPENDIX VIII

Microbiological Counts for Control and Variable Salads

Evaluated During Field Study

Chicken with Almonds Salad

Manufacture date: 6-21-85

Day	<u>Total</u>		<u>Lactobacillus</u>		<u>Psychrotrophic</u>	
	V	C	V	C	V	C
6	290	-	<10	-	<10	-
18	330	290	<10	<10	15	20
25	150	250	<10	<10	15	30

Ham and Cheddar Cheese Salad

Manufacture date: 6-21-85

6	330	-	<10	-	220	-
18	510	180	170	150	50	210
25	4.1×10^4	180	1.2×10^3	130	970	120

Holiday Cole Slaw

Manufacture date: 7-11-85

6	6.5×10^3	-	1.3×10^4	-	7.1×10^3	-
18	1.8×10^4	1.7×10^3	2.2×10^4	9.0×10^3	1.5×10^4	4.3×10^3
25	2.7×10^4	6.9×10^3	3.1×10^4	6.6×10^3	9.6×10^3	2.7×10^3
34	1.4×10^4	1.0×10^4	3.1×10^4	8.3×10^3	3.9×10^3	160

Italian Pasta Salad

-- Manufacture date: 7-11-85

Day	Total		Lactobacillus		Psychrotrophic	
	V	C	V	C	V	C
6	7.5×10^3	-	4.8×10^3	-	800	-
18	6.5×10^3	8.3×10^3	750	10	600	270
25	2.1×10^4	9.8×10^3	830	480	500	170
34	1.3×10^4	8.2×10^3	380	210	100	15

Old Fashioned Potato Salad

Manufacture Date: 8-1-85

6	9.9×10^4	3.6×10^4	6.4×10^5	1.2×10^4	1.8×10^5	1.9×10^4
18	6.6×10^4	4.9×10^4	6.4×10^4	7.0×10^3	5.1×10^4	7.1×10^3
25	1.3×10^5	2.3×10^4	1.4×10^5	9.9×10^3	1.1×10^5	9.2×10^3
34	4.3×10^8	7.0×10^3	2.8×10^4	4.4×10^3	3.1×10^4	8.6×10^3

Seashell Macaroni Salad

Manufacture Date: 8-1-85

6	8.9×10^3	6.5×10^3	1.8×10^3	280	2.0×10^3	265
18	5.9×10^3	5.7×10^3	260	100	300	110
24	6.4×10^3	1.1×10^3	130	130	130	190
34	1.4×10^4	7.0×10^3	400	320	440	50

Seafood Pasta Salad

Manufacture Date: 8-2-85

6	8.4×10^6	1.2×10^5	1.9×10^6	1.9×10^6	1.9×10^6	1.5×10^6
18	2.0×10^5	7.0×10^4	8.0×10^4	5.3×10^4	1.7×10^5	4.8×10^4
25	1.3×10^5	4.7×10^4	2.1×10^5	6.2×10^4	1.8×10^5	6.6×10^4
34	3.5×10^5	5.9×10^4	2.2×10^5	7.5×10^4	2.1×10^5	8.0×10^4

Tropical Delight Fruit Salad

Manufacture Date: 6-22-85

Day	Total		Lactobacillus		Psychrotrophic	
	V	C	V	C	V	C
6	6.4×10^6	-	5.6×10^6	-	10	-
18	3.2×10^6	1.7×10^6	7.9×10^7	5.8×10^7	<10	-
25	6.4×10^4	7.8×10^4	1.6×10^7	2.9×10^6	<10	<10

Vegetable Garden Salad

Manufacture Date: 7-11-85

6	8.7×10^3	-	<10	-	65	-
18	4.3×10^3	8.3×10^3	<10	<10	70	820
25	8.7×10^3	4.6×10^3	<10	<10	90	160
34	4.6×10^3	1.3×10^4	<10	<10	20	300

APPENDIX IX

Statistical Summary of Salad Mean Flavor Scores and Normalized
Reflectance Values of Indicators

Scale for Flavor Scores: 0 to 9

NA: Samples not Available

Salad		Day 6		Day 22	
		Variable	Control	Variable	Control
CSA	Mean, X	6.32	NA	6.26	6.87
	N	39		19	19
	S.D.	0.82		0.81	0.81
HCCS	Mean, X	6.88	NA	6.03	6.03
	N	39		20	20
	S.D.	0.59		1.16	1.06
TDFS	Mean, X	6.60	NA	6.79	6.71
	N	39		19	19
	S.D.	0.98		0.71	0.98
HCS	Mean, X	6.50	6.69	6.08	6.63
	N	19	18	19	19
	S.D.	0.78	0.75	1.08	1.05
	adjR	58	87	38	59
IPS	Mean, X	6.53	6.58	5.61	5.79
	N	20	20	19	19
	S.D.	0.18	0.27	0.31	0.37
	adjR	71	87	42	59

VGS	Mean, X	6.45	6.15	5.35	5.25
	N	19	19	20	20
	S.D.	0.20	0.28	0.28	0.27
	adjR	60	86	37	59
OFPS	Mean, X	6.66	6.58	5.78	6.40
	N	19	19	20	19
	S.D.	0.82	0.79	1.19	1.01
	adjR	71	88	39	58
SMS	Mean, X	6.17	6.60	6.00	6.00
	N	18	20	19	19
	S.D.	0.18	0.23	0.27	0.17
	adjR	69	85	37	60
SPS	Mean, X	6.71	7.06	6.48	6.28
	N	19	18	20	20
	S.D.	0.79	0.42	0.87	1.03
	adjR	80	92	45	64
POST-EXPN					
SPS	Mean, X	5.93	6.05		
	N	20	20		
	S.D.	1.00	1.22		
	adjR	25	42		

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