DISSERTATION

IMPROVING THE SAFETY OF HOME-DRIED FOODS THROUGH MODIFICATION OF TREATMENTS AND EDUCATIONAL PROGRAMS

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY PATRICIA ANN DIPERSIO ENTITILED IMPROVING THE SAFETY OF HOME-DRIED FOODS THROUGH MODIFICATION OF TREATMENTS AND EDUCATIONAL PROGRAMS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

IMPROVING THE SAFETY OF HOME-DRIED FOODS THROUGH MODIFICATION OF TREATMENTS AND EDUCATIONAL PROGRAMS

Microbial illnesses associated with consumption of dried foods raised concerns about the effectiveness of home drying methods for microbial pathogen destruction. Studies at Colorado State University showed that traditional drying methods may allow pathogen survival, and simple modifications enhanced inactivation of *Escherichia coli* O157:H7, *Salmonella* and *Listeria monocytogenes* during home-type dehydration and storage of meat and fruit samples.

Cooperative Extension Services personnel recommend blanching or immersion in a salt solution before drying, or oven heating after drying, to help maintain the quality of home dried vegetables. However, treatments have not been evaluated for their ability to minimize potential pathogen contamination. Guidelines for the preparation of safe and palatable dried foods must be developed, made available to, and adopted by home food preservers to help reduce the risk of foodborne illness potentially associated with such products.

The objectives of the studies were: 1) evaluate *Salmonella* survival on inoculated carrot and potato slices prepared using commonly recommended and modified treatments before drying (60°C, 6 h) to determine their influence on inactivation of the pathogen during dehydration and 30 d of storage; 2) evaluate consumer responses to microbiologically acceptable samples of dehydrated fruits (apple, banana, cantaloupe,

peach, pear, tomato) and vegetables (carrot, potato) prepared using treatments shown to enhance inactivation of pathogens; 3) develop and evaluate a comprehensive food drying bulletin containing acceptable (safety, appearance, taste) drying guidelines for meats, fruits and vegetables that minimized survival of pathogens; and, 4) develop, conduct and evaluate train-the-trainer workshops designed to encourage adoption of recommended guidelines by home food preservers.

Inoculated (*Salmonella*, 7.8 log CFU/g) carrot slices were subjected to commonly recommended treatments, dried (60°C, 6 h) and stored for up to 30 d. Treatments included: 1) control, 2) steam blanching (88°C, 3 min), 3) water blanching (88°C, 3 min), 4) immersion in 3.23% NaCl (25 ± 3°C, 5 min), and 5) oven heating (80°C, 15 min) after drying. Samples were analyzed by spread-plating on tryptic soy agar with 0.1% pyruvate (TSAP) and xylose lysine deoxycholate (XLD) agar for bacterial enumeration. After treatment (control samples were left untreated) and 6 h of dehydration, populations were reduced by 1.3-2.0 (control), 4.0-4.7 (steam blanched), 3.5-4.3 (water blanched) and 1.9-2.6 (3.23% NaCl) log CFU/g. Reductions on samples heated post-drying were 1.7-2.4 log CFU/g. All samples had populations >1.7 log CFU/g after 6 h of dehydration and 30 d of storage. It was concluded that modified treatments must be evaluated for their ability to further inhibit pathogen survival during dehydration and storage of carrot slices.

Inoculated (*Salmonella*, 7.8 log CFU/g) carrot slices were subjected to the following treatments: 1) untreated control, 2) steam blanching (88°C, 10 min), 3) water blanching (88°C, 4 min), 4) blanching in a 0.105% citric acid solution (88°C, 4 min), or 5) blanching in a 0.21% citric acid solution (88°C, 4 min), dried for 6 h at 60°C (140°F), and stored for up to 30 d. Bacterial populations were reduced by 3.8-4.1, 4.6-5.1 and 4.2-

4.6 log CFU/g immediately following steam, water, or citric acid blanching, respectively. After treatment (control samples were left untreated) and 6 h of dehydration, total reductions were 1.6-1.7 (control), 4.0-5.0 (steam blanched), 4.1-4.6 (water blanched) and 4.9-5.4 (blanched in citric acid solution) log CFU/g. Populations were detectable by direct plating at 30 d of storage on all samples except those blanched in 0.21% citric acid. This suggests that blanching carrot slices, particularly blanching in 0.21% citric acid should enhance inactivation of potential *Salmonella* contamination during home-type dehydration and storage.

Methods and treatments described above were used to assess the survival of *Salmonella* during dehydration (60°C, 6 h) and storage (30 d) of potato slices. Initial bacterial populations (6.3-6.6 log CFU/g) were reduced by 4.5-4.8 and >5.4 log CFU/g immediately following steam and water blanching, respectively. After treatment (control samples were left untreated) and dehydration (60°C, 6 h), total *Salmonella* reductions on blanched potato slices (5.3-5.6 log CFU/g) were significantly ($P<0.05$) greater than those on control samples (1.9-2.7 log CFU/g). After 30 d of storage, populations were below the detection limit on all samples except for controls. Blanching treatments used in this study enhanced inactivation of *Salmonella* inoculated onto potato slices and, therefore, may enhance the safety of home dried potato slices if contaminated.

Consumers (n = 280) evaluated the sensory characteristics of dehydrated fruits prepared using treatments shown to enhance pathogen destruction. Apple, banana, cantaloupe, peach, pear and tomato samples were left untreated or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid before dehydration at 60°C. Consumers were primarily female students between the ages of 21 to 34 years. Results showed that

acid treatments maintained or improved the appearance and overall acceptability of dehydrated fruit pieces.

A booklet (*Drying Foods*) and a train-the-trainer workshop were developed and pilot-tested with Master Food Preservers, Cooperative Extension agents and consumers (n=75) to encourage adoption of new food drying guidelines. Social Cognitive Theory and the Health Belief Model were used to guide development of the materials and the workshop. Surveys were used to assess food drying knowledge, attitudes and behavior pre- (immediately before), post (immediately following) and 6 weeks following the workshop. Sensory assessments of dried carrot and potato slices left untreated or blanched in 0.105% or 0.21% citric acid before drying enhanced experiential learning. Knowledge and attitude scores regarding safe food drying methods significantly ($P<0.05$) improved pre- to 6-week follow up evaluation. Participants also indicated improvements in food drying practices 6 weeks prior to attending the workshop. Outcomes indicate improved subject knowledge, attitude and behavior, which may reinforce adoption of new food drying guidelines.

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CHAPTER I

INTRODUCTION

Low moisture foods were once considered unlikely sources of foodborne illness; however, *Escherichia coli* O157:H7 infection and salmonellosis have been associated with consumption of meat jerky, dehydrated milk, infant cereal, chocolate, potato chips and a chip-type savory snack (CDC, 1995a, b, c; Eidson et al., 2000; Kapperud et al., 1990; Killalea et al., 1996; Lehmacher et al., 1995; ProMED-mail, 2003).

Home-dried foods undergo processing steps (handling, washing, cutting) that may introduce pathogens or enhance their growth and, therefore, could present a food safety risk (Brackett, 1999; Beuchat, 2002; Thunberg et al., 2002). Cooperative Extension Services provide recommendations for drying foods at home, yet these recommendations may not always be based on scientific documentation. Albright et al. (2002) reported that beef strips inoculated with *E. coli* O157:H7 (5.7-7.5 log CFU/cm^2) and marinated using a traditional recipe resulted in bacterial reductions of only 2.2 and 3.0-4.6 log CFU/cm^2 after 10 h of drying at 62.5 and 68.3°C, respectively. Albright et al. (2003) also evaluated the effect of alternative treatments on *E. coli* O157:H7 in beef jerky and found that only the hot pickle cure method consistently resulted in a greater than 5-log reduction in bacteria during home-type dehydration. A consumer panel (n=120) rated the jerky as moderately acceptable (3.7-3.9 on a 7-point scale with 7 = extremely acceptable) (Albright et al., 2000). Dipping meat slices in 5% acetic acid (vinegar) followed by

traditional marinade was also shown to enhance reductions of *E. coli* O157:H7 (Calicioglu et al., 2002a), *Salmonella* (Calicioglu et al., 2003), and *Listeria monocytogenes* (Calicioglu et al., 2002b) in beef jerky.

Burnham et al. (2001) evaluated the influence of commonly recommended treatments on *E. coli* O157:H7 inoculated onto apple slices before dehydration. Steam blanching (88.3°C, 3 min) had little effect on pathogen destruction but immersion in 3.4% ascorbic acid prior to dehydration induced a 5-log reduction during drying at 57.2°C or 62.8°C. Derrickson-Tharrington et al. (2005) found similar results for *E. coli* O157:H7 inoculated apple slices immersed in 1.7% citric acid solution before home-type dehydration. After 6 h of drying, populations were reduced by 6.7 to 7.3 log CFU/g on acid treated slices compared to only a 2.2 to 3.1 log CFU/g reduction on untreated samples. DiPersio et al. (2003) evaluated whether immersing inoculated apple slices in a 3.4% ascorbic acid or 0.21% citric acid altered survival of *Salmonella* during dehydration (60°C, 6 h) and storage. Treatment with organic acids generally enhanced bacterial reductions after 6 h of dehydration and 28 d of storage. Similar results were reported for peach slices inoculated with *L. monocytogenes*, dried (60°C, 6 h) and stored for up to 14 d (DiPersio et al., 2004a). Yoon et al. (2004) determined that peeling and blanching combined with immersion in 3.4% ascorbic acid or 0.21% citric acid minimized the survival of *Salmonella* during home-type dehydration (60°C, 14 h) and storage (28 d) of tomato halves. The acceptability of dehydrated fruits prepared using modified treatments was not assessed.

Cooperative Extension Services recommend blanching or immersion in a salt solution before drying, or oven heating after drying, to help maintain the quality and

extend the shelf life of home-dried vegetables (Brennand, 1994; Dinstel, 1999; Hughes and Willenberg, 1994; Kendall and Allen, 1998; Mixon, 2004; Okoli et al., 1988; Reynolds and Williams, 1993; Roberts and Cox, 1999; Swanson, 1995). However, treatments have not been evaluated for their ability to inhibit or destroy potential pathogen contamination during the preparation and storage of home-dried vegetables.

Illnesses associated with dried foods have raised concerns about the safety of home drying recommendations. Studies showed traditional drying methods may allow pathogen survival, and that simple modifications enhanced pathogen inactivation during dehydration and storage of meat and fruit samples (Albright et al., 2002; Albright et al., 2003; Burnham et al., 2001; Calicioglu et al., 2002a, b; Calicioglu et al., 2003, Derrickson-Tharrington et al., 2005; DiPersio et al., 2003; DiPersio et al., 2004a; Yoon et al., 2004). Methods for the preparation of home-dried vegetables must be evaluated for their ability to minimize pathogen survival during dehydration and storage. Guidelines for the safe and palatable preparation of dried meats, fruits and vegetables must be made available to, and adopted by home food preservers. The objectives of this research were to:

1) Evaluate *Salmonella* survival on inoculated carrot slices prepared using commonly recommended treatments before drying (60°C, 6 h) to determine whether treatments altered inactivation of the pathogen. The FDA requires that minimally processed (unpasteurized) fruit juices and cider undergo treatment(s) that consistently result in a ≥5-log reduction in the most resistant microorganism of public health significance likely to occur in the product (FDA, 1998; CFR, 2001). The same standard has been set for the proposed work.

2) Evaluate *Salmonella* survival on inoculated carrot and potato slices exposed to modified treatments (longer blanching times, acid blanching), dried (60°C, 6 h), and stored for up to 30 d to determine their influence on inactivation of the pathogen. Specifically, develop treatments or combinations of treatments that effect a 5-log reduction of *Salmonella* populations on dehydrated carrot and potato slices.

3) Evaluate consumer responses to microbiologically acceptable samples of dehydrated fruits (apple, banana, cantaloupe, peach, pear, tomato) and vegetables (carrot, potato) prepared using treatments shown to enhance inactivation of pathogens. Uninoculated products, with or without exposure to treatments, were evaluated for sensory characteristics (appearance, flavor, color, texture and overall acceptability) on a 9-point hedonic scale. Surveys were designed according to guidelines set by the Institute of Food Technologists (IFT, 1981) and included questions related to the preparation, handling, storage and consumption of home-dried foods.

4) With the assistance of literature regarding survival of *Salmonella, E. coli* O157:H7 and *L. monocytogenes*, and home food drying recommendations made by Cooperative Extension Services, develop and evaluate a comprehensive food drying bulletin containing acceptable (safety, appearance, taste) drying guidelines for jerky, fruits and vegetables that minimized survival of pathogens. Recommendations on home drying meats, fruits and vegetables were collected into a comprehensive bulletin. Experts in the field of food safety, Master Food Preservers, Extension agents, 4Hers enrolled in food preservation and consumers evaluated the bulletin for readability, likeability, willingness to follow and overall acceptability. Feedback was used to guide the modification of content and format of the bulletin.

5) Develop and evaluate train-the-trainer workshops designed to encourage adoption of modified food drying procedures by Master Food Preservers, Extension agents, 4-Hers enrolled in food preservation and consumers. Social Cognitive Theory and The Health Belief Model were used to develop theory-driven, research-based train-the-trainer workshops that promoted revised recommendations on safe home drying of meats, fruits and vegetables. The two-hour workshops included background information on foodborne pathogens, general food safety information, and recommendations on the safe preparation, handling and storage of home-dried foods. Elements of the Health Belief Model were used to develop pre-, post and follow up evaluation instruments to assess compliance with new behavior, and changes in knowledge and attitudes as a result of the workshops. Educational activities were designed to provide participants with both an understanding of why changes are recommended and the skills to teach others how to make the changes.

CHAPTER II

LITERATURE REVIEW

Foodborne illness and low moisture foods. Low moisture foods were once considered unlikely sources of foodborne illness; however, *Escherichia coli* O157:H7 infection and salmonellosis have been associated with consumption of low moisture foods such as meat jerky, potato chips, chocolate, dehydrated milk and a savory corn snack (CDC, 1995a, b, c; Eidson et al., 2000; Kapperud et al., 1990; Keene et al., 1997; Killalea et al., 1996; Lehmacher et al., 1995; ProMED-mail, 2003). In 1994, an outbreak of *E. coli* O157:H7 was associated with dried, fermented, ready-to-eat salami in Washington and California (CDC, 1995b). In 1995, an outbreak of *E. coli* O157:H7 occurred in Oregon involving home-made deer jerky. As many as 11 persons were infected (Keene et al., 1997). In the same year, an outbreak of *E. coli* O111:NM infection was associated with contaminated semi-dry fermented sausage which lead to hemolytic uremic syndrome in 23 Australian children (CDC, 1995c).

In New Mexico between 1966 and 1995, eight gastroenteritis outbreaks due to ingestion of meat jerky contaminated with *Salmonella* and *Staphylococcus aureus* resulted in 250 illnesses (Eidson et al., 2000). Locally produced beef jerky was implicated in the outbreak. In 2003, an outbreak of salmonellosis related to commercially produced beef jerky made in New Mexico affected at least 22 persons (ProMED-mail, 2003). In Germany, a large outbreak of salmonellosis resulting in an estimated 1000

illnesses was traced to contaminated paprika-powdered potato chips (Lehmacher et al., 1995). Levels of 0.04 to 0.45 organisms per gram were found in the chips leading investigators to conclude that even extremely low numbers of salmonellae adapted to the dry state are able to cause illness (Lehmacher et al., 1995).

The cumulative prevalence from 1990 to 1999 of *Salmonella* and *Listeria monocytogenes* in jerky produced in federally inspected plants was found to be 0.31% and 0.52%, respectively (Levine et al., 2001). Because *L. monocytogenes* is believed to be an environmental contaminant, and listeriosis has a high fatality rate in high risk populations, the Food Safety and Inspection Service (FSIS) established a zero tolerance (no detectable level permitted) for the pathogen in ready-to-eat products since it began testing in 1987. Beef jerky, dry and semi-dry fermented sausages, large and small diameter sausages, salads and spreads, cooked beef and poultry, and luncheon meats are included in the monitoring program (FSIS, 1999). Outbreak reports emphasize the risk for foodborne illness associated with consumption of low moisture foods and the need for more research on pathogen survival in these products.

Foodborne illness and produce. Within the last 25 years, foodborne illness outbreaks associated with fresh and minimally processed produce have increased (Beuchat, 2002; CDC, 1999; Garrett et al., 2003; Mead et al., 1999; Natvig et al., 2002; Sivapalasingam et al., 2003; Thunberg et al., 2002). Minimally processed fruits and vegetables seem to be associated with foodborne illness more frequently than fresh, whole produce (Brackett, 1999; Conway et al., 2000; Garrett et al., 2003). This may be because the peel or rind provides a physical and chemical barrier which prevents the establishment of microbes on edible surfaces (CDC, 1990; Conway et al., 2000). This barrier is removed during

processing and may result in the establishment of pathogen cells, leading to increased risk of foodborne illness (Conway et al., 2000; Garrett et al., 2003; Ken-Ichi et al., 1999). Outbreaks have been associated with consumption of improperly processed and/or mishandled alfalfa sprouts, apple cider, apple juice, berries, cantaloupe, cilantro, lettuce, mangoes, orange juice, potatoes, tomatoes and watermelon (Burnett and Beuchat, 2000; Garrett et al., 2003; Liao and Cooke, 2001; PHLS, 2000; Sagoo et al., 2003; Sivapalasingam et al., 2003; Sivapalasingam et al., 2004; Stafford, 2001).

***Escherichia coli* O157:H7.** *E. coli* is a gram-negative, non-sporing rod differentiated on the basis of surface antigens O (somatic), H (flagella) and K (capsule) (Riley et al., 1983). *E. coli* is categorized into seven groups according to virulence properties, clinical syndromes, differences in epidemiology and surface antigens. Serogroups include enteropathogenic *E. coli*, enteroinvasive *E. coli*, enterotoxigenic *E. coli*, enterohemorrhagic *E. coli*, enteroaggregative *E. coli*, uropathogenic *E. coli* and neonatal meningitis *E. coli* (Tauxe, 1997). Diseases caused by the enterohemorrhagic serogroup include hemorrhagic colitis and hemolytic uremic syndrome. Infection is characterized by abdominal cramps, watery/bloody diarrhea, renal failure and/or death (CDC, 1995c; Griffin and Tauxe, 1991). *E. coli* O157:H7 has become a major concern in foods because of the severe consequences of infection (especially in children, the elderly and the immunocompromised), its low infectious dose (may be less than ten cells) and its high acid tolerance (Cody et al., 1999; Keene et al., 1994; Ryu et al., 1999).

E. coli O157:H7 infection is often associated with consumption of undercooked meats (CDC, 2001). However, outbreaks have been associated with contaminated fresh cantaloupe, lettuce and watermelon (Ackers, 1998; Diaz and Hotchkiss, 1996;

Janisiewicz et al., 1999), unpasteurized apple juice (Cody et al., 1999; Steele et al., 1982), and unpasteurized apple cider (Besser et al., 1993). The Food and Drug Administration (FDA) has published a regulation requiring a warning statement on unpasteurized juices and cider that states: "WARNING: This product has not been pasteurized and, therefore, may contain harmful bacteria which can cause serious illness in children, the elderly, and persons with weakened immune systems" (CFR, 2001). Furthermore, the FDA requires that processors of juice products include in their HACCP plans control measures that consistently produce a ≥5-log reduction in the most resistant microorganism of public health significance that is likely to occur in the product (CFR, 2001).

Salmonella. *Salmonella* are gram-negative, non-sporing rods of the family *Enterobacteriaceae*. *Salmonella* species have the ability to grow between 5.5°C and 45°C, with optimum proliferation at approximately 37°C. The genus consists of over 2,600 serovars; all are considered human pathogens. The *Salmonella* genus is divided into two species, *Salmonella bongori* and *Salmonella enterica*. *Salmonella enterica* includes the serovars responsible for both typhoidal and non-typhoidal salmonellosis. Non-typhoidal salmonellosis is a localized, self-limiting infection of the intestinal epithelium. Symptoms of infection include abdominal pain, diarrhea, nausea, vomiting and fever. Typhoidal salmonellosis is a systemic infection characterized by fever, headache, abdominal pain and constipation. Severe cases of typhoidal and non-typhoidal salmonellosis infection may lead to pneumonia, cystitis, septic arthritis, meningitis and/or death (Gahan and Hill, 1999; PHLS, 2000a). Estimates of infectious dose vary due to factors such as bacterial strain, type of food, preparation and storage conditions of the food, and the age and health status of the consumer (Kapperud et al., 1990).

Traditionally, outbreaks of salmonellosis have been associated with consumption of raw or undercooked animal foods, or water contaminated with fecal matter (Bean et al., 1997). Recently, documented foodborne illness outbreaks associated with consumption of raw fruits and vegetables have increased in the United States (Sivapalasingam et al., 2004). In fact, *Salmonella* is the most prevalent pathogen associated with produce and has been isolated from fresh market samples of bean sprouts, cauliflower, cilantro, eggplant, endive, lettuce, melons, peppers, spinach, sprouts and tomatoes (Beuchat, 2002; Johannessen et al., 2002; Tauxe et al., 1997; Thunberg et al., 2002). Salmonellosis has been associated with consumption of raw or minimally processed alfalfa sprouts, berries, cantaloupe, lettuce, mango, tomatoes, watermelon, and unpasteurized apple and orange juices (Burnett and Beuchat, 2000; Liao and Cooke, 2001; PHLS, 2000a; PHLS, 2000b; Sagoo et al., 2003; Sivapalasingam et al., 2004; Stafford, 2001). The prevalence of *Salmonella* in raw or minimally processed produce is generally low; however, the pathogen can quickly grow to high populations and exist in the absence of sensory defects (Brackett, 1999). For example, *Salmonella* grew quickly (reaching 8 log CFU/g within 24 h) in chopped tomatoes at ambient temperature (Zhuang et al., 1995). Golden et al. (1993) found that *Salmonella* may grow rapidly on fresh cut cantaloupe, honeydew and watermelon at 23°C; populations increased by 5 to 7 log CFU/g in 24 h.

Listeria monocytogenes. *L. monocytogenes* is a gram-positive, non-sporeforming, facultatively anaerobic rod of the *Listeriaceae* family, and is able to grow between -1.5°C and 45°C (Donnelly, 2001). It is a well-adapted microorganism able to survive, and even proliferate, under adverse conditions. Although the listeriae grow best in the pH range 6-

8, several researchers have shown that this species is able to grow in a pH range of 4.1 to 9.6 (Lou and Yousef, 1999). All 14 *L. monocytogenes* serovars cause listeriosis; however, serovars 1/2a, 1/2b, and 4b cause the majority of cases (Tappero et al., 1995). The ingestion of viable cells is necessary for listeriosis infection to occur; foodborne transmission is the predominant means of infection. Human illness caused by *L. monocytogenes* usually occurs in high-risk groups including pregnant women, neonates and immunocompromised adults, but may occasionally occur in persons who have no predisposing underlying conditioned (Donnelly, 2001). In contrast to the mild flu-like illness seen in maternal listeriosis, transplacental infection of the fetus may result in abortion, still birth, neonatal meningitis and/or the premature birth of a severely septic infant. In non-pregnant humans, listeriosis is most common among immunocompromised adults and the elderly. Infection may result in septicemia, meningitis, meningoencephalitis and/or death (Donnelly, 2001; Schlech, 1996).

Listeria is widely distributed in nature and has been isolated from the feces of animals, which is a potential source of fresh produce contamination (Schlech et al., 1983). *L. monocytogenes* has been observed to grow on fresh or processed asparagus, broccoli, cucumbers, onions and potatoes (Beuchat, 2000; Burnett and Beuchat, 2002; PHLS, 2000b; Sivapalasingam et al., 2004). Produce implicated in listeriosis outbreaks include cabbage, coleslaw, celery, lettuce, potatoes and tomatoes (Beuchat and Brackett 1990; Burnett and Beuchat, 2002; Conway et al., 2000; Heisick et al., 1989; Lehmacher et al., 1995).

Preservation factors. Dehydration is the oldest and most common form of food preservation (Salunkhe and Kadam, 1995). Decreasing the moisture content of fresh

foods provides a wider variety of meats, fruits and vegetables throughout the year. Today, drying is used extensively in cultures where electrical energy is expensive or nonexistent to limit the need for long-term, low-temperature storage. For the North American home food preserver, drying is a way to produce specialty foods for gifts, snacks and recreational back packing (VanGarde and Woodburn, 1994).

The primary reason most foods are dried is to reduce spoilage due to bacteria, yeasts and molds. The dehydration process often uses air to supply heat to a food and carry moisture vapor away from the drying product (Desrosier and Desrosier, 1977). Appropriate air circulation and temperature must be maintained throughout dehydration to produce a high quality, shelf stable product. When heat is applied too rapidly, the outer layer of the food dries too quickly (case hardening) and prevents further moisture release from the center of the food (Nichols, 1978). Case hardening and moisture retention in dried foods leads to rapid spoilage and, if present, the potential survival of harmful bacteria.

Foodborne pathogens exhibit a wide range of resistance responses to stresses such as heat, low water activity and low pH (Bower and Daeschel, 1999). The ability of pathogens to develop multi-stress resistance (Garrett et al., 2003; Lou and Yousef, 1997; Rowe and Kirk, 1999), and become more virulent as a result of stress exposure (Gahan and Hill, 1999; O'Driscoll et al., 1996), makes it difficult to predict or control their survival in foods. A combination of destruction factors may inhibit or destroy bacterial pathogens more effectively than any one factor. For example, a heat treatment such as drying, combined with blanching and/or organic acid treatments, together may be more effective than the heat treatment alone at enhancing reductions of bacterial pathogens in

home-dried foods (Albright et al., 2002; Albright et al., 2003; Burnham et al., 2001; Calicioglu et al., 2002a, b; Calicioglu et al., 2003, Derrickson-Tharrington et al., 2005; DiPersio et al., 2003; DiPersio et al., 2004a; Yoon et al., 2004).

Heat. Wuytack et al. (2002) studied the inactivation of *Salmonella* by heat and indicated that heat is known to cause cell membrane damage, protein denaturation and the denaturation of nucleic acids. Most likely, all of these targets are hit simultaneously to cause sublethal and lethal damage to bacterial cells. However, food processing techniques that alter total solids, acidity, or water activity of food may actually improve the thermotolerance of bacterial contaminants and allow them to survive (Doyle and Mazzotta, 2000). Furthermore, processing conditions that injure, but do not effectively kill all pathogenic cells, could result in the repair and growth of damaged survivors (Novak and Juneja, 2001). Inactivation of pathogenic bacteria by heat is often used in food processing. Under experimental conditions, most vegetative bacterial pathogens are killed by exposure to temperatures of 55-60°C for 3 h or less (Epstein, 1997). However, Droffner and Brinton (1995) showed that *Salmonella* and *E. coli* O157:H7 were detectable for up to 59 d in aerobically composted manure maintained at a temperature of 60°C. It was concluded that pathogen destruction is a complex process and can not be guaranteed by established thermal standards. It is important to note that improperly composted manure has been implicated as a source of pathogen contamination in fresh and minimally processed produce (Burnett and Beuchat, 2000; Tauxe et al., 1997).

Previous growth conditions may influence the heat resistance of some pathogenic bacteria (Doyle and Mazzotta, 2000). Several authors have noted that Salmonellae and *L. monocytogenes* grown at high temperatures or exposed to sublethal heat shock may

display heat resistance. Furthermore, certain pathogens are able to recover heat damage in foods when subsequent storage is under anaerobic conditions (Garrett et al., 2003; Manas et al., 2001; Novak and Juneja, 2001). Research has shown that microorganisms can develop heat resistance and, therefore, heating alone may not reduce the risk of pathogen survival, or enhance the safety of home-dried foods if pathogens are present (Albright et al., 2002; Albright et al., 2003; Burnham et al., 2001; Calicioglu et al., 2002a, b; Calicioglu et al., 2003, Derrickson-Tharrington et al., 2005; DiPersio et al., 2003; DiPersio et al., 2004a; Doyle and Mazzotta, 2000; Yoon et al., 2004).

Drying. Most spoilage bacteria do not grow below a water activity of 0.91, while most molds can grow at a water activity of 0.80. The lowest water activity for bacterial growth is 0.75 (halophilic). Xerophilic (dry-loving) molds and osmophilic (preferring high osmotic pressures) yeasts can grow at water activity values of 0.60 and 0.61, respectively (Jay, 2000). Dehydrated fruits and meats are popular snacks, while dried vegetables are often reconstituted and added to other foods when the raw product is not available (Harrison and Andress, 1999). Meat jerky must have a water activity of $\leq$0.85 (Faith et al., 1998). Properly dried jerky is chewy and leathery. Dehydrated fruits and vegetables should be dried to a water activity below 0.60. Fruits dried to a proper endpoint feel pliable and contain no pockets of moisture after cooled. Most vegetables are sufficiently dried and characteristically brittle when dehydrated to 0.30 water activity (Mazza, 1983).

Home-dried foods are minimally processed and often consumed without further treatment that would normally inactivate harmful microorganisms. Previous studies indicated that dehydration alone effectively destroyed foodborne pathogens; however,

recent data support the potential for pathogen survival and development of resistances during drying, and the ability of survivors to recover from injury in dried foods (Albright et al., 2002; Albright et al., 2003; Burnham et al., 2001; Calicioglu et al., 2002a, b; Calicioglu et al., 2003, Derrickson-Tharrington et al., 2005; DiPersio et al., 2003; DiPersio et al., 2004a; Mattick et al., 2001; Waterman and Small, 1998; Yoon et al., 2004). Although Salmonellae cannot grow at a water activity of less than 0.945, *S.* Typhimurium DT104 survived at a water activity of 0.92 for long periods of time (Mattick et al., 2001). Miller (1991) determined that *L. monocytogenes* was able to grow at a water activity of 0.90, while Shahamat et al. (1980) found that *L. monocytogenes* (serotype 1/2a) survived longer than 100 d in a salt solution with a water activity of 0.80. Sumner et al. (1991) showed that at 65.6°C, *Salmonella* had a *D*-value of 0.29 min at a water activity of 0.98 and 40.2 min at a water activity of 0.83. At the same temperature, *L. monocytogenes* had a *D*-value of 0.36 min at a water activity of 0.98 and 3.8 min at a water activity of 0.90. It was concluded that the heat resistance of *S.* Typhimurium and *L. monocytogenes* increased as water activity decreased at levels tested. Research indicates that foodborne pathogens may survive, recover from injury and/or develop resistances during heating and, therefore, dehydration alone may not improve the safety of home-dried foods if pathogens are present (Albright et al., 2002; Albright et al., 2003; Burnham et al., 2001; Calicioglu et al., 2002a, b; Calicioglu et al., 2003, Derrickson-Tharrington et al., 2005; DiPersio et al., 2003; DiPersio et al., 2004a; Waterman and Small, 1998; Yoon et al., 2004).

Acid. Foodborne illness associated unpasteurized apple and orange juices have increased awareness of the presence of pathogens in foods previously considered too

acidic to serve as vehicles for transmission of illness (Burnett and Beuchat, 2000; CDC, 1999; DeRoever, 1998). The ability of bacterial pathogens to survive and grow in acidic foods has lead to research on the acid tolerance of these organisms. Acid tolerant and acid resistant bacteria have a better chance of survival on acidic foods such as apples, oranges and their products (Ryu et al., 1999). Acid tolerance must be induced in a microorganism, while acid resistance is an inherent characteristic. Acid adaptation or acid shock induces acid tolerance. Acid adaptation occurs when a microorganism has undergone extended exposure to a weak acid or has been grown in the presence of fermentable carbohydrates, while acid shock occurs when the microorganism is suddenly shifted from neutral to low pH (pH≤5.8) (Ryu et al., 1999). Pickett and Murano (1996) studied whether exposure to sublethal levels of organic acids (chemical shock) affected survival of *L. monocytogenes* after subsequent exposure to the same acids at various concentrations. It was determined that chemical shock induced by exposure (1 h) to sublethal levels of citric acid enabled *L. monocytogenes* to survive subsequent exposure to lethal levels of the acid.

Organic acids are used as antibrowning agents, antioxidants and antimicrobials; they act individually or in combination to inhibit growth of microorganisms in foods (Giannuzzi and Zaritzky, 1992). Type and concentration of acid, temperature and the characteristics of target organisms all influence the antimicrobial activity of organic acids (Gil et al., 1998). Uljas and Ingham (1999) studied the effect of preservation methods on *S.* Typhimurium DT104 and *E. coli* O157:H7 in 3.3, 3.7 and 4.1 pH apple cider. Short term storage and/or freeze-thawing (-20°C, 48 h; 4°C, 4 h) of cider with or without 0.1% lactic, sorbic, or propionic acids were tested. In pH 3.3 cider, a 5 log CFU/ml reduction of *E. coli* O157:H7 was achieved by freeze/thawing or storage for 6 h at 35°C. In pH 4.1

cider, the same reduction was achieved after freeze/thawing and 6 h storage at 35°C, addition of 0.1% sorbic acid and 6 h storage at 35°C, and addition of 0.1% sorbic acid, 4h storage at 35°C and freeze/thawing. The pH of apple cider was an important determinant affecting the severity of treatments needed to achieve a 5 log CFU/ml reduction in pathogen populations. It was concluded that a 5 log CFU/ml reduction in *S.* Typhimurium DT104 and *E. coli* O157:H7 populations in apple cider may be achieved by combining short term storage, freezing and thawing, and/or addition of organic acids (Uljas and Ingham, 1999).

Oxidative reactions in foods involve the removal of electrons from atoms or molecules, the creation of free radicals, and the development of undesirable flavors, discoloration of pigments and changes in texture (Dzeizak, 1986). Oxidation is catalyzed by several factors including oxygen, heat and alkaline conditions. Ascorbic acid (Vitamin C) acts as an antioxidant in foods by binding oxygen and becoming oxidized to dehydroascorbic acid, a stable molecule which does not initiate further oxidative reactions (Dzeizak, 1986). As an antioxidant, ascorbic acid works synergistically with other antioxidants by promoting their antioxidative action. For example, ascorbic acid regenerates phenolic antioxidants by contributing hydrogen atoms to phenoxyl radicals produced during lipid oxidation (Dzeizak, 1986).

Ascorbic acid is generally recognized as safe (GRAS) for use as a chemical preservative (21 CFR 182.3013) and helps maintain the color of dried fruits by inhibiting nonenzymatic and enzymatic browning. Most of the browning that occurs in dehydrated foods is via the Maillard reaction (nonenzymatic browning) which may cause undesirable changes in appearance and flavor. Nonenzymatic browning involves oxidation reactions

between carbonyl groups of a reducing sugar and amine groups of a protein causing the formation of yellow, brown or black pigments called melanoidins (Davidek et al., 1990; Moline et al., 1995). The Maillard reaction functions in a specific pH range and, therefore, immersing light colored fruits in an ascorbic acid solution prior to dehydration will reduce pH and inhibit nonenzymatic browning (VanGarde and Woodburn, 1994).

Cutting fruits promotes enzymatic browning by permiting phenolic compounds to mix with endogenous polyphenol oxidase (PPO) and facilitating diffusion of atmospheric oxygen into the tissue. Hydroxylation of *o*-diphenols by PPO converts them to *o*-quinones, which are polymerized into brown pigments. Ascorbic acid minimizes PPO browning by reducing *o*-quinones back to phenolic compounds before they form brown pigments (Gil et al., 1998). In a study to evaluate the effect of ascorbic acid on browning of Fuji apple slices, acid treated samples were found to be lighter in color than untreated apple slices (Gil et al., 1998).

Ascorbic acid functions as an antibrowning agent in dried foods; however, its degradation can actually potentiate browning during the dehydration process (Negi and Roy, 2001). Ascorbic acid is easily oxidized to dehydroascorbic acid during heating and, if oxidation continues, it can not be reversed (Negi and Roy, 2001). Dehydroascorbic acid is then available to react with proteins, propagate their degradation (Strecker degradation), and promote the formation of brown pigments (Davidek et al., 1990). Furthermore, flavor notes produced via Strecker degradation may cause undesirable flavor changes in the finished product (Davidek et al., 1990).

Citric acid is the main component of lemon juice and is used as a preservative in fresh and minimally processed produce (Venkitanarayanan and Wolf-Hall, 2002). For

example, citric acid has been used for decades to inhibit enzymatic and nonenzymatic browning (Maillard reaction) in home-dried fruit (Gil et al., 1998). The antimicrobial activity of citric acid is thought to be due to its pH- lowering ability (Chien, 1992). Under acidic conditions, undissociated molecules diffuse through the bacterial cell membrane and, once inside the cell, dissociate into charged ions which are then unable to re-cross the membrane (Booth and Krol, 1998). Citric acid accumulates within the cytoplasm, disrupts metabolic functions, prompts a stress response and depletes energy reserves needed for survival and growth (Bracey et al., 1998). Although highly acidic solutions are excellent antimicrobials, they may not be appropriate for certain foods. Weissinger and Beuchat (2000) evaluated citric acid for its effectiveness in killing *Salmonella* on alfalfa seeds. Immersing inoculated seeds in 5% citric acid for 10 min resulted in reductions of 2 to 3 log CFU/g. However, the treatment did not reduce the number of *Salmonella* on alfalfa seeds by more than 2.2 log CFU/g without significantly ($P<0.05$) reducing germination percentage. Treatment with a high concentration of citric acid was considered impractical for use on alfalfa seeds meant for germination. It was concluded that preserving foods with a combination of antimicrobial agents and temperature may maximize the destruction of pathogens while retaining the quality and acceptability of the final product.

Chelating agents are not antioxidants but help stabilize foods by binding pro-oxidative metal ions, potentiating antioxidants and/or inactivating enzymes that cause color and flavor deterioration (Dziezak, 1986). Citric acid is a chelating agent used in the preservation of dried fruits, vegetables and meats, and is regarded as GRAS by the FDA (21 CFR 182.3013). Moline et al. (1995) found that citric acid was more effective than

ascorbic acid as an antibrowning agent in fresh cut banana slices stored at 5°C for up to 7 days. The fact that ascorbic acid is an effective antibrowning agent in other fruits such as apples may indicate that bananas and apples contain different types and/or concentrations of enzymes and substrates. Differences in pH may also account for dissimilar browning rates among fruits (Moline et al., 1995).

Combining Preservation Factors. A combination of factors may be more effective than one factor alone at enhancing destruction of potential pathogen contamination, and preserving the quality of dried foods. Alzamora et al. (1989) examined the preservation of minimally processed fruit slices using a combination of destruction factors. Mild heat, low water activity, low pH, and addition of sodium bisulfite and potassium sorbate, were found to produce shelf stable pineapple slices. Vijayanand et al. (2001) examined the shelf life and microbiological quality of pineapple and mango chunks preserved by a combination of processes. Fruit pieces were blanched in 0.6% citric acid (85°C, 5 min), immersed in a potassium metabisulfite/sodium benzoate solution (8 h), vacuum packaged, and stored for up to 60 d. Samples had acceptable sensory and microbiological qualities for up to 30 d at 27°C and 60 d at 2°C. It was concluded that the combination of low pH, mild heat, preservatives and packaging lengthened the shelf stability of minimally processed pineapple and mango chunks. Venkitanarayanan et al. (2002) studied the ability of combined processes to inactivate *E.coli* O157:H7, *S.* Enteritidis and *L. monocytogenes* inoculated onto fresh apples, oranges and tomatoes. A solution of 1.5% lactic acid plus 1.5% hydrogen peroxide, applied at 40°C for 15 min, resulted in a reduction of ≥5.0 log CFU per fruit of all three pathogens. Furthermore, sensory panelists could not perceive significant differences ($P>0.05$) between treated and control apples. It

was concluded that the combination of processes enhanced destruction of *E.coli* O157:H7, *S.* Enteritidis and *L. monocytogenes* on fresh apples, oranges and tomatoes but did not affect sensory and quality characteristics.

Research has shown that a combination of treatments including heat, drying and low pH had a greater effect on the inactivation of pathogens in dried meats and fruits than any of the individual factors used alone (Albright et al., 2002; Albright et al., 2003; Burnham et al., 2001; Calicioglu et al., 2002a, b; Calicioglu et al., 2003, Derrickson-Tharrington et al., 2005; DiPersio et al., 2003; DiPersio et al., 2004a; Yoon et al., 2004). Studies are needed to evaluate treatments for their ability to control the safety, quality and stability of home-dried vegetables. Methods must be easy to follow and readily available to home food preservers.

Drying foods at home. Cooperative Extension Services have traditionally provided recommendations for drying foods at home; yet these recommendations are not always based on scientific documentation. The increased incidence of foodborne illness associated with dried foods and traditionally "low risk" foods, including minimally processed fruits and vegetables, has prompted the need for more research in the area of home food drying (CDC, 1995a, b, c; CDC, 1999).

Jerky. Meat jerky is a dehydrated meat often prepared in the home and consumed without further cooking. Outbreaks of foodborne illness associated with home-dried meat jerky suggest bacteria may survive traditional methods used by home food preservers (Eidson et al., 2000; Keene et al., 1997). Albright et al. (2003) found that beef strips inoculated with a 4-strain mixture of *E. coli* O157:H7 (5.7-7.5 log CFU/cm^2), marinated using a traditional recipe, stored 24 h at 4°C, and dried at 62.5 or 68.3°C, resulted in

bacterial reductions of 2.2 and 3.0-4.6 log CFU/cm^2 after 10 h of drying. Investigators concluded that further studies were needed to develop treatments to adequately inhibit or destroy *E. coli* O157:H7 during home-type dehydration of beef jerky. In a similar study, researchers reported on the viability of *E. coli* O157:H7 in beef jerky prepared at levels of 5 and 20% fat and dried at 52, 57, 63, and 68°C in home-style dehydrators. Higher drying temperatures produced greater lethality, and higher fat content reduced lethality of *E. coli* O157:H7 during home-type dehydration. It was concluded that jerky should be prepared from leaner cuts of meat and dried at ≥ 63°C (145°F) for at least 8 hours. It was noted that temperatures on dehydrator control dials and empirical measurements were significantly different by 3-22°C indicating that dehydrator temperature should be monitored during drying (Faith et al., 1998).

The USDA Meat and Poultry Hotline recommends cooking meats to 71.1°C (160°F) before drying to reduce the risk of pathogen survival and improve the safety of the product. However, jerky prepared by this method has an unacceptable flavor and texture to some consumers and, therefore, alternative methods are needed (Kendall, 2000a). Albright et al. (2003) studied the fate of *E. coli* O157:H7 in beef jerky prepared using four pre-drying treatments and dried in home-type dehydrators for up to 10 h at 62.5°C, then stored at 21°C for up to 90 d. Only the hot pickle cure method resulted in a greater than 5-log reduction in bacteria during drying (5.7-5.8 log CFU/cm^2). Immersing beef slices in a warm vinegar/water solution (2.5% acetic acid; 57.5°C) for 20 seconds before or after traditional marinade (Reynolds and Williams, 1993) resulted in bacterial reductions of 4.7-5.2 log CFU/cm^2. Populations continued to decline throughout storage (21°C) and were undetectable by direct plating on all samples at day 30 (Albright et al.,

2003). A consumer panel (n=120) rated the jerky as moderately acceptable (3.7-3.9 on a 7-point scale with 7 = extremely acceptable) (Albright et al., 2000).

Studies were conducted to assess the ability of acid-modified marinades to reduce pathogen populations during home style drying of jerky. Beef slices were inoculated with *Salmonella*, *E. coli* O157:H7 or *L. monocytogenes*, marinated for 1 h (4°C) in a traditional marinade, or in the same marinade with added citric acid (3.7%) or ascorbic acid (7.7%), then dried 10 h at 62.5°C. Acidified marinades generally produced greater reductions of bacteria during drying compared to the traditional marinade. It was concluded that acidified marinades may enhance bacterial inactivation during home-type dehydration of beef jerky (Calicioglu et al., 2002b; Calicioglu et al., 2003a; Derrickson-Tharrington et al., 2005).

Studies were also conducted to evaluate the effectiveness of modified marinades to inactivate acid-adapted and unadapted *Salmonella, E. coli* O157:H7 and *L. monocytogenes* inoculated on beef jerky prior to marination and after drying (Calicioglu et al., 2002a-b, 2003). Treatments included: 1) control, no treatment; 2) traditional marinade (pH 4.3) and; 3) dipping in 5% acetic acid (pH 2.5) for 10 min followed by traditional marinade. Following marination, slices were held 24 h at 4°C then dried (10 h, 60°C) in home-style dehydrators. Reductions in *E. coli* O157:H7 populations after 10 h drying were 4.8-6.5 log CFU/cm^2 for the vinegar-marinade jerky, and lower for the traditional marinade and control jerky (2.8-4.9 and 3.1-5.3 log CFU/cm^2, respectively). Similar reductions were seen in *Salmonella* and *L. monocytogenes* populations. Bacterial populations continued to decline throughout storage and dropped below the detection limit as early as day 0 (after drying) or as late at day 60, depending on acid adaptation,

pre-drying treatment and agar medium. It was concluded that acid adaptation did not increase resistance to the combined treatments used in jerky processing and that the use of organic acids in jerky marination improved the effectiveness of drying on inactivation of *Salmonella* (Calicioglu et al., 2003a), *E. coli* O157:H7 (Calicioglu et al., 2002a) and *L. monocytogenes* (Calicioglu et al., 2002b).

The same treatments were evaluated for their antimicrobial effects when contamination occurred post drying. Jerky was prepared using the treatments described above, dried 10 h at 60°C, inoculated with acid-adapted and non-adapted *E. coli* O157:H7 and stored at 25°C under aerobic conditions for up to 60 d. Populations decreased faster on jerky inoculated with acid-adapted cultures than with non-adapted cultures for all treatments. A 5-log reduction in pathogen populations was achieved within 7 d for the vinegar-marinade treatment, and never achieved for the control and traditional marinade treatments (Calicioglu et al., 2003b). Similar trends were found for jerky products inoculated post drying with *Salmonella* (Calicioglu et al., 2003d) and *L. monocytogenes* (Calicioglu et al., 2003c). It was concluded that the use of modified marinades in jerky processing may reduce the risk of pathogen survival when contamination occurs post-drying.

Several factors affect the safety of home-dried jerky including variations in dehydrator temperature, fat content of the meat, marinade ingredients and acidity, and variation in the time and temperature of dehydration (Eidson et al., 2000). These factors are difficult to control for the home food preserver. Based on studies into preparing meat jerky in the home, the USDA recommends cooking meats to 71°C (160°F) followed by drying at 54-60°C (130-140°F) in a standard home dehydrator (USDA-FSIS, 2000).

Alternative methods for enhancing bacterial inactivation during home style drying of meat jerky include the hot pickle cure method and immersing beef slices in vinegar for 10 minutes, followed by traditional marination and drying for 10 h at 60-62.5°C (Kendall and Sofos, 2003). Recipes and additional topics of concern for the safe and palatable preparation of meat jerky must be made available to consumers. One way would be to include the information in Cooperative Extension publications available to consumers for purchase or on the web (Kendall, 2000b; Kendall and Sofos, 2003; USDA-FSIS, 2000).

Fruits. Fresh produce may become contaminated with pathogenic organisms in the field and processing plant, as well as in the home due to improper handling, preparation and storage (Beuchat and Ryu, 1997; Ken-Ichi et al., 1999; Thunberg et al., 2002). *E. coli* O157:H7 infection, salmonellosis and listeriosis have been associated with consumption of fresh and minimally processed berries, cantaloupe, tomatoes, watermelon, and unpastuerized apple and orange juices (Beuchat, 1995; Burnett and Beuchat, 2000; Liao and Cooke, 2001; PHLS, 2000a; PHLS, 2000b; Sagoo et al., 2003; Stafford, 2001). The Food and Drug Administration Center for Food Safety and Applied Nutrition (FDA/CFSAN) estimated the risk of developing listeriosis through consumption of raw or dried fruit as low (FDA/CFSAN, 2003). Nevertheless, *L. monocytogenes* has been isolated from fresh market samples of strawberries and unpasteurized fruit juices (Johannessen et al. 2002; Sado et al., 1998).

Cooperative Extension Services provide recommendations for dehydrating fruits at home. A survey was conducted in the spring of 2001 of home food drying recommendations made by Cooperative Extension Services in the United States. An electronic letter was sent to Cooperative Extension Services in the 50 states requesting

copies of their home food drying recommendations. Information was returned from 27 states (DiPersio et al., 2003). Treating fruits with blanching or immersion in acidic solutions were recommended to preserve the color and quality of home-dried fruits. To evaluate the combination of treatments and drying on the inactivation of *E. coli* O157:H7 on apple slices, Burnham et al. (2001) immersed inoculated apple slices for 15 min in a 3.4% ascorbic acid solution or steam blanched (88.3°C, 3 min) them prior to dehydration at 57.2°C or 62.8°C for 6 h. Untreated (control) apple slices had a 2.9 log CFU/g reduction of *E. coli* O157:H7 following 6 h of dehydration. Steam blanching had little effect on the destruction of bacteria, while the ascorbic acid solution induced a 5-log reduction during drying at both temperatures.

In a similar study, DiPersio et al. (2003) evaluated whether treating inoculated Gala apple slices with acidic or metabisulfite solutions altered survival of *Salmonella* during dehydration and storage. After drying, populations on untreated samples were reduced by 2.8 to 4.2 log CFU/g, while populations on samples treated with sodium metabisulfite, ascorbic acid (3.4%), or citric acid (0.21%) were reduced by 3.8 to 5.7 log CFU/g. Bacteria were detectable after 28 d of storage, except on slices treated with ascorbic acid. It was concluded that immersion in 3.4% ascorbic acid solution before drying enhanced inactivation of *Salmonella* during home-type dehydration and storage of apple slices. In a follow up study, DiPersio et al. (2004) evaluate the inactivation of *L. monocytogenes* on inoculated peach slices during drying to determine whether treating inoculated slices with metabisulfite or acidic solutions prior to drying altered inactivation during home style dehydration and storage. Inoculated (7.9 log CFU/g) peach slices were left untreated or immersed (10 min) in sterile water, 4.18% sodium metabisulfite, 3.4%

ascorbic acid or 0.21% citric acid. Immersion in water reduced *L. monocytogenes* populations on peach slices by 0.7 log CFU/g. Immersion in the sodium metabisulfite solution reduced populations by 1.5-2.0 log CFU/g, while acidic treatments reduced populations by 0.5-0.8 log CFU/g. After 6 h of dehydration, populations on control or water immersed slices were reduced by 3.2-3.4 log CFU/g, whereas populations on slices treated with sodium metabisulfite or acidic solutions were reduced by 4.3-6.2 log CFU/g. Bacteria were detectable by direct plating at 14 d of storage at ambient temperature, except on acid treated slices. It was concluded that immersion in 4.18% sodium metabisulfite, 3.4% ascorbic acid or 0.21% citric acid solutions, prior to dehydration of peach slices, should be useful in enhancing inactivation of potential *L. monocytogenes* contamination. It is important to note that sulfite treatments are not recommended for those with sulfur sensitivity or asthma. Yoon et al. (2004) reported that peeling and blanching, combined with immersion in 3.4% ascorbic acid or 0.21% citric acid, enhanced inactivation of *Salmonella* during home-type dehydration (60°C, 14 h) and storage of tomato halves. Researchers have shown that immersion in sodium metabisulfite or acidic solutions, alone or in combination with blanching, enhanced reductions of bacterial populations on inoculated fruit slices prior to home-type dehydration and storage. More research is needed to evaluate the sensory characteristics (appearance, flavor) of the finished product and develop guidelines for home food preservers.

Vegetables. Dehydrated mushrooms and asparagus have long been known to be contaminated occasionally with *Salmonella* (Lehmacher et al., 1995). Furthermore, an international outbreak of salmonellosis has been traced to contaminated paprika-

powdered potato chips (Lehmacher et al., 1995). Cooperative Extension Services recommend steam blanching, water blanching or immersion in a salt solution before drying, or oven heating after drying, to inhibit browning and/or extend the shelf life of home-dried vegetables (Brennand, 1994; Brewer, 1992; Herringshaw, 1997; Hughes and Willenberg, 1999; Kendall and Allen, 1994; Mixon, 1998; Reynolds and Williams, 1993; Roberts and Cox, 1999; Swanson, 1995). Although these treatments improve color and quality, they may not improve the safety of the finished product when contaminated. For example, *E. coli* O157:H7 inoculated onto parsley treated with commonly recommended methods was still detectable by direct plating after 90 d of storage at ambient temperature. Current vegetable drying recommendations need to be evaluated for their ability to inhibit or destroy pathogens and, if necessary, modified treatments must be developed. Treatments should produce a safe, high quality, shelf stable product that is acceptable to consumers.

Sensory evaluation. The Sensory Division of the Institute of Food Technologists (IFT) defines sensory evaluation as "a scientific discipline used to evoke, measure, analyze and interpret reactions to characteristics of foods as perceived by sight, smell, taste, touch and hearing" (IFT, 1981). Three types of sensory tests are discrimination, descriptive and affective (acceptance-preference). Discrimination tests are divided into two groups, difference and sensitivity. Difference tests determine if there is a difference between or among samples. Sensitivity tests determine the lowest concentration of substance detectable (absolute or detection threshold) or required for identification (recognition or identification threshold) (Penfield and Campbell, 1990).

Descriptive testing characterizes and/or compares samples with respect to one or

more characteristics and includes attribute rating, texture or flavor profiling and descriptive analysis. For attribute rating, panelists rate products on scales that represent a range of low to high intensity of a characteristic. To obtain useful information about the quality of a product, scales should not reflect just the opinions of panelists. The terms desirable, acceptable and undesirable are appropriate for affective testing but not descriptive evaluation. Texture profiling evaluates mechanical, geometrical, fat and moisture properties of food (brittle, soft) and flavor profiling analyzes character notes (tart, sweet) (IFT, 1981; Penfield and Campbell, 1990).

Affective testing determines if panelists like a product, if they prefer one product to another and/or if they intend to use a product (acceptance). Large consumer panels (50-100) of untrained judges often are used in this type of evaluation. The most commonly used evaluation technique for measuring acceptability and/or preference is the hedonic scale. The word hedonic is defined as "pertaining to, or consisting in, pleasure". Hedonic scales usually include five to nine points and are anchored by phrases such as "dislike extremely" and "like extremely" (Meilgaard et al., 1988; Penfield and Campbell, 1990).

Food safety in the home. Food processors cannot ensure the absolute safety of their products and, therefore, home food preparers are an important player in the line of defense against foodborne illness (Medeiros et al., 2001). From 1973 to 1987, homes accounted for 21% of reported outbreaks when the preparation site of the implicated food was identified (Bean et al., 1997). However, illnesses resulting from improper food preparation in the home are likely to be much more common because sporadic cases and outbreaks involving small numbers of people are rarely reported (Knabel, 1995). In fact,

Knabel (1995) suggested that most cases of foodborne illness result from small outbreaks or single cases due to unsafe food preparation in the home. However, research indicates that most consumers are not aware of this fact. Fein et al. (1995) reported on telephone surveys conducted in 1988 and 1993 that dealt with consumer perceptions of foodborne illness. Sixty five percent of participants who had suffered from a foodborne illness believed that the implicated food had been prepared in a restaurant; only 17% believed that the suspect food had been prepared at home. Walker (1996) conducted an in-home food safety survey and found that while people were aware of proper food handling techniques, and believed they were important, very few changed their food handling practices. In a similar study, Worsfold and Griffith (1997) observed 108 participants preparing a prescribed set of recipes in their homes. Sixty six percent of participants did not wash their hands before beginning food preparation and 41% did not wash some or all vegetables before use. It was determined that the problem was not only consumer ignorance but that consumers were not convinced to change their behaviors. Bruhn and Schutz (1999) conducted a mail survey to evaluate consumer food handling knowledge and behaviors. Although 50% of participants indicated concern about microbiological hazards, 22% were unsure what to do to minimize their risk from bacterial contamination. It was concluded that while many consumers were concerned about microbiological hazards, they often either did not take action or did not know what action to take. Results of these studies indicate that if consumers misperceive the nature and origin of foodborne illness, prevention will be difficult. Furthermore, consumers will be less motivated to change if they believe that serious consequences of foodborne illness are infrequent and if they fail to associate their home practices with perceived illness. Behavior theorists

suggest that in addition to increasing knowledge, effective food safety education must also raise consumer awareness about food safety risks and then motivate consumers to change their food-related behaviors (Medeiros et al., 2001).

Social Cognitive Theory. According to Bandura's Social Cognitive Theory (SCT), a desired outcome occurs due to a combination of outcome expectations and self-efficacy (Bandura, 1977; Bandura, 1989). Outcome expectancy is a person's estimate that a behavior will lead to certain outcomes; an efficacy expectation is the belief that one can successfully execute the behavior required to produce the outcomes (Bandura, 1989). Self-efficacy proposes that an individuals' confidence in their ability to perform a task or behavior determines which behaviors they will engage in, how long they will persist, and how much effort they will expend to achieve their goals (Bandura, 1989). Self-efficacy has been show to be a powerful predictor of health behavior (AbuSabha and Achterberg, 1997). In intervention studies, increases in knowledge, training, experience, and/or familiarity with a task are likely to result in increases in self-efficacy scores for that task, which in turn is likely to change behavior toward accomplishing the task (AbuSabha and Achterberg, 1997). Other components of the SCT include behavioral capabilities, modeling/observational learning and social support. Behavioral capabilities include the knowledge of a behavior and the skills acquired to perform the behavior. One learns to watch others and observe the reinforcements that others receive in modeling and observational learning. According to the SCT, encouraging hands-on participation in food safety workshops reinforces self-efficacy and observational learning, and may lead to the adoption of new behaviors (Bandura, 1977; Bandura, 1989).

Health Belief Model. The Health Belief Model (HBM) is one of the most influential and

widely used psychosocial approaches to explaining health-related behavior (Glanz et al., 1990; Janz and Becker, 1984). Perceived threat (risk), perceived benefits and perceived barriers are important components of the model. Beliefs regarding the effectiveness of actions in reducing disease threat are the perceived benefits of taking health action. Perceived barriers may act as impediments to undertaking recommended behaviors (Glanz et al., 1990). Thus, perceived threat/risk of disease provides the force to act and the perception of benefits (less barriers) provides a preferred path of action toward the adoption of positive health-related behaviors (Rosenstock and Kirscht, 1974). Hanson and Benedict (2002) measured the association among HBM variables and safe food handling behaviors of consumers. Variables measured included perceived threat of foodborne illness, cues to action (i.e., media and educational materials) and safe food handling behaviors. Cues to action were positively related to perceived threat of foodborne illness and safe food handling behaviors. Perceived severity of foodborne illness was positively related to sanitation, a dimension of safe food handling behavior. Findings reinforced the usefulness of cues to action but did not provide strong evidence of a relationship between perceived threat of foodborne illness and safe food handling behaviors. Researchers concluded that educational materials describing safe food handling practices might be more beneficial than materials that focus primarily on the threat of foodborne illness. Results agree with previous studies that clearly establish the need to target audiences with food safety messages specifically designed for them (Gettings and Kiernan, 2001; Hanson and Benedict, 2002).

Evaluating food safety education. Food safety education programs can influence food handling practices among consumers and contribute to minimizing foodborne illness

(Goldberg et al., 1990; McGrandy, 1988; Medeiros et al., 2001). Validity (the ability to measure the phenomenon intended to be measured) and reliability (the consistency of results when applied repeatedly) are important to establish for evaluation tools used in educational programs (Medeiros et al., 2001; Medeiros et al., 2004; Monsen et al., 1991). If instruments are unreliable or not valid, the measurement of program outcomes will be inaccurate. However, reliability and validity checks are not commonly done in food safety education, thus there is a critical need for instruments that have been tested for validity and reliability (Medeiros et al., 2001; Medeiros et al., 2004).

The increased incidence of foodborne illness associated with traditionally "low risk" foods such as home prepared meat jerky and minimally processed produce has prompted the need for more research in the area of home food drying (CDC, 1999; Keene et al., 1997; Lehmacher et al., 1995; Nummer et al., 2004; ProMED-mail, 2003; Sivapalasingam et al., 2004). The objectives of this research were to:

1) Evaluate *Salmonella* survival on inoculated carrot slices prepared suing commonly recommended treatments before drying to determine their influence on inactivation of the pathogen. *Salmonella* is the most prevalent pathogen associated with produce (Thunberg et al., 2002) and survived for up to 28 d in dehydrated apple slices (DiPersio et al., 2003) and, therefore, is appropriate for use in the proposed studies. The FDA requires that minimally processed (unpasteurized) fruit juices and cider undergo treatment(s) that consistently result in a $\geq$5-log reduction in the most resistant microorganism of public health significance likely to occur in the product (FDA, 1998; CFR, 2001). The same standard has been set for the proposed work.

2) Evaluate *Salmonella* survival on inoculated carrot and potato slices treated with

modified treatments (longer blanching times, acid blanching), dried (60°C, 6 h), and stored for up to 30 d to determine whether treatments alter inactivation of the pathogen. Specifically, develop treatments or combinations of treatments that effect a 5-log reduction of *Salmonella* populations on dehydrated carrot and potato slices.

3) Evaluate consumer responses to microbiologically acceptable samples of dehydrated fruits (apple, banana, cantaloupe, peach, pear, tomato) and vegetables (carrot, potato) prepared using treatments shown to enhance inactivation of *Salmonella.* Uninoculated products, with or without exposure to treatments, were evaluated for sensory characteristics (appearance, flavor, color, texture and overall acceptability) on a 9-point hedonic scale. Surveys were designed according to guidelines set by the Institute of Food Technologists (IFT, 1981) and included questions related to the preparation, handling, storage and consumption of home-dried foods.

4) With the assistance of literature regarding survival of *Salmonella, E. coli* O157:H7 and *L. monocytogenes*, and home food drying recommendations made by Cooperative Extension Services, develop and evaluate a comprehensive food drying bulletin containing acceptable (safety, appearance, taste) drying guidelines for jerky, fruits and vegetables that minimize survival of pathogens. Recommendations on home drying meats, fruits and vegetables were collected into a comprehensive bulletin. Experts in the field of food safety, Master Food Preservers, Extension agents, 4Hers enrolled in food preservation and consumers evaluated the bulletin for readability, likeability, willingness to follow and overall acceptability. Feedback was used to guide the modification of content and format of the bulletin.

5) Develop and evaluate train-the-trainer workshops designed to encourage adoption

of recommended procedures by Master Food Preservers, Extension agents, 4-Hers enrolled in food preservation and consumers. Social Cognitive Theory and The Health Belief Model were used to develop theory-driven, research-based train-the-trainer workshops that promoted revised recommendations on safe home drying of meats, fruits and vegetables. The two-hour workshops included background information on foodborne pathogens, general food safety information, and recommendations on the safe preparation, handling and storage of home-dried foods. Elements of the Health Belief Model were used to develop pre-, post and follow up evaluation instruments to assess compliance with new behavior, and changes in knowledge and attitudes as a result of the workshops. Educational activities were designed to provide participants with both an understanding of why changes are recommended and the skills to teach others how to make the changes.

CHAPTER III

INACTIVATION OF *SALMONELLA* DURING DRYING AND STORAGE OF CARROT SLICES PREPARED USING COMMONLY RECOMMENDED METHODS

ABSTRACT

This study evaluated the influence of drying treatments and aerobic storage (25°C, 30 d) on inactivation of a five-strain mixture of *Salmonella* (7.8 log CFU/g) on carrot slices. Treatments included: 1) control, 2) steam blanching (88°C, 3 min), 3) water blanching (88°C, 3 min), 4) immersion in 3.23% NaCl (25 ± 3°C, 5 min), and 5) oven heating (80°C, 15 min) after drying. Treatments were selected from recommendations made by Cooperative Extension Services for ability to maintain characteristics of dried vegetables and possible antimicrobial effects. Carrot slices were inoculated with the *Salmonella* mixture, left for 15 min to allow for attachment, then treated (steam blanched, water blanched, or 3.23% NaCl immersion) and dehydrated (60°C, 6 h), or left untreated, dehydrated (60°C, 6 h), and heated (80°C, 15 min). Samples were analyzed by spread-plating on tryptic soy agar with 0.1% pyruvate (TSAP) and xylose lysine deoxycholate (XLD) agar for bacterial enumeration. Initial populations (6.96-7.18 log CFU/g) were reduced by 3.2-3.3 log CFU/g immediately after steam or water blanching, and by 0.6 log CFU/g following immersion in 3.23% NaCl. After treatment and 6 h of dehydration, total reductions were 1.3-2.0 (control), 4.0-4.7 (steam blanched), 3.5-4.3 (water blanched) and

1.9-2.6 (3.23% NaCl) log CFU/g. Reductions on samples heated post-drying were 1.7-2.4 log CFU/g. All samples had populations >1.7 log CFU/g after 6 h of drying and 30 d of storage at 25°C and, therefore, may not enhance the safety of the final product if contaminated. Modified treatments are needed to further enhance inactivation of *Salmonella* on dehydrated carrots.

Introduction

Numerous fruits and vegetables have been linked to *Salmonella* infection, including alfalfa sprouts, apple products, cantaloupe, lettuce, orange juice, tomatoes and watermelon (Burnett and Beuchat, 2000; Kapperud et al., 1990; Liao and Cooke, 2001). *Salmonella* might be present on produce owing to contaminated soil, irrigation water, feces and inadequately composted manure (Beuchat, 2002; Burnett and Beuchat, 2000; Endley et al., 2003; Tassou and Boziaris, 2002; Tauxe et al., 1997). Vegetables such as carrots are not only at risk of becoming contaminated with pathogens while in the field, but also during postharvest handling, processing and distribution (Beuchat and Ryu, 1997; Endley et al., 2003; Tassou and Boziaris, 2002). Postharvest contamination may result from tainted harvest equipment, wash and rinse water, and transport vehicles, as well as improper storage, processing, and packaging (Beuchat, 1996; Burnett and Beuchat, 2000; DeRoever, 1998; Endley et al., 2003; Janisiewicz et al., 1999).

The prevalence of *Salmonella* in minimally processed produce is generally low; however, the pathogen can quickly grow to high populations and exist in the absence of apparent sensory defects (Brackett, 1999). For example, *Salmonella* grew quickly (reaching 8 log CFU/g within 24 h) in chopped tomatoes at ambient temperature (Zhuang et al., 1995). Golden et al. (1993) found that *Salmonella* may grow rapidly on fresh cut

cantaloupe, honeydew and watermelon at 23°C; populations increased by 5 to 7 log CFU/g over 24 h.

One of the oldest methods for preserving vegetables is dehydration (Desrosier and Desrosier, 1977). Dehydration involves the addition of heat to a food to evaporate inherent moisture and preserve the food from spoilage. Household food drying often uses air to supply heat to a food and carry moisture vapor away from the drying product (Desrosier and Desrosier, 1977). The optimum water activity for dried vegetables is generally between 0.20 and 0.30 (Van Garde and Woodburn, 1994). Minimal processing, such as dehydration, may merely injure pathogenic bacteria without eliminating them from a food or reducing their ability to cause foodborne illness (Uljas and Ingham, 1999).

Foodborne illness has resulted from ingestion of contaminated paprika-powdered potato chips. The infective dose was estimated at 4 to 45 cells, proving that even extremely low numbers of salmonellae adapted to the dry state are able to cause illness (Lehmacher et al., 1995). Beef jerky, a cereal-based snack chip, chocolate, dried milk and infant cereal are low water activity foods that also have been associated with salmonellosis outbreaks (CDC, 1995; Greenwood and Hooper, 1983; Killalea et al., 1996; Mattick et al., 2001; Rushdy et al., 1998). Carrots were chosen for the present study because of their consistency and availability throughout the year, their popularity among home food preservers and the lack of published studies on the survival of *Salmonella* in home-dried carrots.

To evaluate the combination of pre-drying treatments and drying on the inactivation of *Escherichia coli* O157:H7 on apple slices, Burnham et al. (2001) immersed inoculated apple slices for 15 min in a 3.4% ascorbic acid solution or steam

blanched (88.3°C, 3 min) them prior to dehydration at 57.2°C or 62.8°C for 6 h. It was found that steam blanching had little effect as a pre-drying treatment on the destruction of bacteria, while the ascorbic acid solution induced a 5-log reduction during drying at both temperatures.

DiPersio et al. (2003) evaluated whether treating inoculated Gala apple slices with acid or metabisulfite solutions altered survival of *Salmonella* during dehydration and storage. After drying (60°C, 6 h), populations on control samples were reduced by 2.8 to 4.2 log CFU/g, while populations on samples treated with sodium metabisulfite, ascorbic acid (3.4%), or citric acid (0.21%) were reduced by 3.8 to 5.7 log CFU/g. Bacteria were detectable after 28 d of storage, except on slices treated with ascorbic acid. It was concluded that immersion in 3.4% ascorbic acid solution, prior to dehydration, should be useful in enhancing the inactivation of *Salmonella* contamination during drying and storage of apple slices.

Yoon et al. (2004) evaluated the influence of treatments including peeling, blanching and dipping in organic acid solutions, drying at 60°C for 14 h and storage at 25°C for 28 d on inactivation of *Salmonella* inoculated (~ 7 log CFU/g) on Roma tomatoes. It was concluded that peeling and blanching, combined with immersion in 3.4% ascorbic acid or 0.21% citric acid, enhanced inactivation of *Salmonella* during dehydration of tomato halves.

Based on the literature cited, *Salmonella* may pose a food safety risk from dehydrated foods such as carrot slices. This study was designed to evaluate the effect of current Cooperative Extension vegetable drying recommendations on the survival of *Salmonella*. Specifically, the objective of this study was to evaluate the survival of

Salmonella on inoculated carrot slices treated with steam blanching, water blanching, or immersion in a 3.23% NaCl solution before drying, or oven heating after drying, and determine whether these recommended treatments altered inactivation of the pathogen during dehydration and storage.

Materials and Methods

Preliminary work. A survey was conducted in the spring of 2001 of home food drying recommendations made by Cooperative Extension Services. An electronic letter was sent to Cooperative Extension Services in the 50 states requesting copies of their home food drying recommendations. Information was returned from 16 states (Table 3.1) (Andress and Harrison, 1999; Archuleta, 2000; Brennand, 1994; Brewer, 1992; Dinstel, 1997; Wolf et al., 1990; Herringshaw, 1997; Hughes and Willenberg, 1999; Kendall and Allen, 1998; Mixon, 2004; Penner et al., 1983; Reynolds et al., 1993; Roberts and Cox, 1999; Swanson, 1995; Taylor, 2001).

Preparation of inoculum. The inoculum suspension consisted of *Salmonella* Typhimurium strains ATCC14028 and ATCC700408, F530 isolated from an equine outbreak (provided by Dr. J.W. Foster, University of South Alabama, Mobile, AL), *S.* Agona isolated from alfalfa sprouts (provided by Dr. L.R. Beuchat, University of Georgia, Griffin, GA), and *S.* Copenhagen isolated from cattle hides.

Inocula of each strain were prepared in tryptic soy broth (TSB, Difco, Beckton Dickinson Co, Sparks, MD) by incubation without agitation at 35°C for 24 h. Cell suspensions of each strain were centrifuged (4629 × g, 4°C, 15 min) and suspended in 10 ml of phosphate buffered saline (PBS, pH 7.4; 0.2g KH_2PO_4, 1.5g $Na_2HPO_4.7H_2O$, 8.0g NaCl and 0.2g KCl in 1liter distilled water). The five suspensions of cells were combined

Table 3.1. Carrot dehydration procedures in 16 sets of Cooperative Extension Service recommendations[a].

State	Carrot Preparation and Dehydration Procedures	Blanching Time (min)		Salt Water Dip	Post-drying
		Steam	Water		Oven Heating
Alaska	Peel and slice; dry 140-150°F until tough and leathery	none	2	none	Reheat 175°F, 10-15 min
Georgia, Missouri, Colorado	Slice 1/8" thick; dry 140°F for 10-12 h	3-3.5	3-3.5	none	None
	Peel and slice 1/8" thick; dry until tough to brittle	3-4	4	none	Reheat 150°F, 30 min or 175°F for 15 min
Florida	Peel and slice 3/8" thick; dry 140°F for 2 h then 130°C for 4-8 h	3-4	none	none	not necessary
Idaho, Oregon, Wa. State	Slice 1/4" thick; dry 140-150°F for 2-3 h, then dry 130-140°F for 7-9 h	3-4	none	Prep. 2-4 Tbsp. salt per 1 gallon water; soak 2-5 min, drain	none
Illinois	Slice 1/8-1/4" thick; dry 150°F for 1-2 h, then 140°F for 2-10 h (until brittle)	1-3; rinse	none	Prep. 2-4 Tbsp. salt per 1 gallon water; soak 1 min, drain	Reheat 175°F, 15 min
Kansas	Slice up to 3/8" thick; dry 145°F for 4-12 h	3-5	none	none	none
Minnesota	Slice 1/4" thick; dry 140-145°F for 6-8 h	4	3	none	none
Mississippi	Slice 1/8" thick; dry 160°F until visible moisture is gone, then dry 140°F (total 2-4 h)	8-10	none	none	Reheat 175°F, 15 min or 160°F, 30 min
New Mexico	Slice 1/8" thick; dry 140-150°F until tough to brittle (4-12 h)	3-4	4	none	none
Ohio	Peel and slice 1/4-1/8" thick; dry 140°F until brittle, deep orange	3	none	none	none
Utah	Slice 1/8" thick; dry 140-160°F for 2.5-4 h	3-4	1.5-2	Prep. 4-6 Tbsp. salt per 1 gallon water; soak 10 min	Reheat 150°F, 30 min
Virginia	Slice 1/8" thick; dry 140°F for 3.5-5 h	3-3.5	3-3.5	none	Reheat 150°F, 30 min or 160°F, 10 min

[a] Information compiled from 16 sets of Cooperative Extension Service home vegetable drying recommendations. Indiana, Nevada, New Jersey, North Carolina, North Dakota, Rhode Island and Wyoming Cooperative Extension Services reported that they neither published nor distributed produce drying recommendations.

to form a composite, which was re-centrifuged and re-suspended in 100 ml of PBS. Cell populations (8.1 log CFU/ml) in the composite inocula were determined by plating on tryptic soy agar with 0.1% sodium pyruvate (TSAP, Difco) and incubating for 24 h at 35°C.

Preparation and inoculation of carrot slices. Nantes variety carrots were purchased in June through August 2003 at a local grocery store, washed, peeled and sliced crosswise into 1/8" thick slices. Each sample consisted of 12 carrot slices that weighed approximately 18 ± 2g. Carrot slices were arranged on plastic trays covered with aluminum foil. Under a laminar-flow hood, 0.25 ml of the *Salmonella* inoculum was spread onto the top surface of each slice and allowed to attach for 15 min at ambient temperature (approximately 25 ± 3°C). Slices were then turned over and the other side inoculated following the same procedure. The mean inoculation level of carrot slices was 7.2 ± 0.2 log CFU/g.

Treatments. Following inoculation, carrot slices were exposed to one of five treatments: 1) inoculated untreated control, 2) steam blanching (88°C, 3 min), 3) water blanching (88°C, 3 min), 4) immersion in 3.23% NaCl solution (25 ± 3°C, 5 min), or 5) no treatment pre-drying and oven heating (80°C, 15 min) post-drying. All inoculated carrot slices were dried for 6 h at 60°C. After dehydration, carrot slices that received no pre-drying treatment were either set aside and used as control samples (i.e., underwent no further treatment) or underwent post-drying oven heating (80°C, 15 min).

Steam and water blanching procedures (88°C, 3 min) used in this study were derived from the times and temperatures most often listed in existing home-drying recommendations (Hughes and Willenberg, 1999; Kendall and Allen, 1998; Reynolds et al., 1993; Roberts and Cox, 1999; Swanson, 1995). The amount of sodium chloride used was derived from the highest levels listed in Cooperative Extension home-drying publications (6 tablespoons per gallon of

water) (Brennand, 1994). This amount was found to be equivalent to 122.3 g (calculated from the average of 10 independent measurements of 6 level tablespoons of sodium chloride) per 3785 ml water (3.23%). The post-drying oven heating procedure (80°C, 15 min) most frequently recommended in Cooperative Extension home-drying literature was used in this study (Brewer, 1992; Dinstel, 1997; Kendall and Allen, 1998; Mixon, 2004).

Dehydration. The inoculated, treated and untreated carrot slices were dehydrated for 6 h at 60°C (140°F) in four American Harvest Gardenmaster dehydrators (model FD-1000, Nesco, Chaska, MN) simultaneously such that each of the three trays of each dehydrator contained slices from all samples. The dehydrators were preheated to 60°C (140°F) for approximately 30 min, trays were loaded with inoculated carrot slices from each treatment, and the internal temperature of the slices was monitored throughout drying using thermocouples (Pico Technology, Cambridge, UK). Probes were inserted into each of 12 carrot slices, one slice from each tray of each dehydrator, and temperatures were recorded with real-time data recording software (Pico Technology). Circulating air temperature within the dehydrators was also monitored and recorded over the 6 h drying period using four thermocouple probes (Pico Technology) inserted through the center opening of each dehydrator. Dehydrator trays were cleaned with warm soapy water, soaked (24 h, 23°C) in a 5% bleach solution (Clorox, Oakland, CA) and rinsed in distilled water between replicates.

Sampling for analysis. For each treatment, one sample consisted of 12 carrot slices, one slice randomly selected from within the treatment slices on each of the three trays in each of the four dehydrators. Two samples per treatment were taken immediately after inoculation, after blanching or immersion in the NaCl solution (treated samples only) (0 h), at 1.5, 3, 4.5 and 6 h of drying, after 6h of drying and 15 min of oven heating, and on days 5, 15 and 30 of storage at 25

± 3°C and 30 ± 6% relative humidity (Digital Relative Humidity Meter, Control Company, Friendswood, TX). An extra slice from each treatment was analyzed immediately for water activity (at each sampling time including after inoculation but before treatment, after inoculation and treatment but before drying, at 1.5, 3, 4.5 and 6 h of drying, after 6 h of drying and 15 min of heating, and on days 5, 15, and 30 of storage).

Each 12-slice sample was aseptically transferred to an 18 oz sterile plastic bag (Nasco, Modesto, CA) at each sampling interval. The weights of the samples were recorded, maximum recovery diluent (MRD, 1.0g Bacto ™ Peptone and 8.5g sodium chloride in 1 L distilled water [Difco]) (Mattick et al., 2002) was added to each sample to total 21.5g and the bags were pummeled (IUL Instruments, Barcelona, Spain) for 120 sec at ambient temperature (25 ± 3°C).

Microbial analysis. Serial decimal dilutions were made in 9 ml of 0.1% sterile buffered peptone water (BPW, Difco) and each sample was surface plated on tryptic soy agar plus 0.1% pyruvate (TSAP, Difco) and xylose lysine deoxycholate (XLD, Difco) agar and incubated at 35°C for 24 h. All colonies for each agar were counted manually. Mean numbers of colonies were used to determine the colony forming units per gram (CFU/g) of carrot and converted into log values. The formula used for converting the counts from plates into log CFU/g was: $W \times X \times (Y + Z)/Z$ where W is the average colony count from duplicate plates; X is the dilution factor; Y is the amount of MRD; and Z is the weight of carrot slices at each sampling time. When bacterial counts dropped below the detection limit, the *Salmonella* enrichment, isolation and identification methods outlined in the Food and Drug Administration Bacteriological Analytical Manual (2001) were followed.

Other analyses. The pH values of samples from all treatments and times of testing were determined after microbial analysis with a pH meter and a glass electrode (Denver Instruments,

Arvada, CO). The water activity values of samples from all treatments at all sampling times were determined with a Rotronic water activity meter (model AwQUICK, Rotronic Instrument Corp., Huntington, NY).

Statistical analysis. The drying experiment was replicated three times and the data were analyzed using a 4 × 5 × 2 × 3 factorial design with 4 (number of treatments, including controls) × 5 (number of time intervals when samples were analyzed, i.e. after treatment (or 0 h), and at 1.5 h, 3 h, 4.5 h, and 6 h) × 2 (number of agar media) × 3 (number of replicates) factors. The post-drying oven heated samples were analyzed separately using one drying time (6 h 15 min). Storage data were analyzed using a 5 × 4 × 3 factorial design with 5 (number of treatments, including controls) × 4 (number of time intervals when samples were analyzed, i.e. after treatment and 6 h of drying (0 d), and at 5, 15 and 30 d of storage at 25 ± 3°C and 30 ± 6% relative humidity) × 3 (number of replicates) factors. For each replicate, the mean represented the average of two samples converted into log CFU/g. All data analyses were conducted with the Statistical Analysis System (SAS Institute version 9.1, Cary, NC) for analysis of variance of main (fixed) effects and all interactions between fixed effects. When F-values were significant ($P<0.05$), least significant differences (LSD) in surviving bacterial population counts between treatments were determined using the ANOVA mixed model procedure of SAS.

Results and Discussion

Dehydrator air and carrot slice temperature. Insertion of the pre-loaded trays into the dehydrators reduced the mean circulating air temperature in the four dehydrators from 60°C to 47.9 ± 3.3°C at 0 h of dehydration; the average temperature of the carrot slices at 0 h was 37.1 ± 17.6°C (Figure 3.1 and Table A3.1). The average temperature of the circulating air and carrot slices reached 59.8 to 60°C by 2.5 h of drying (Figure 3.1 and Table A3.1). From 2.5 to 6 h of

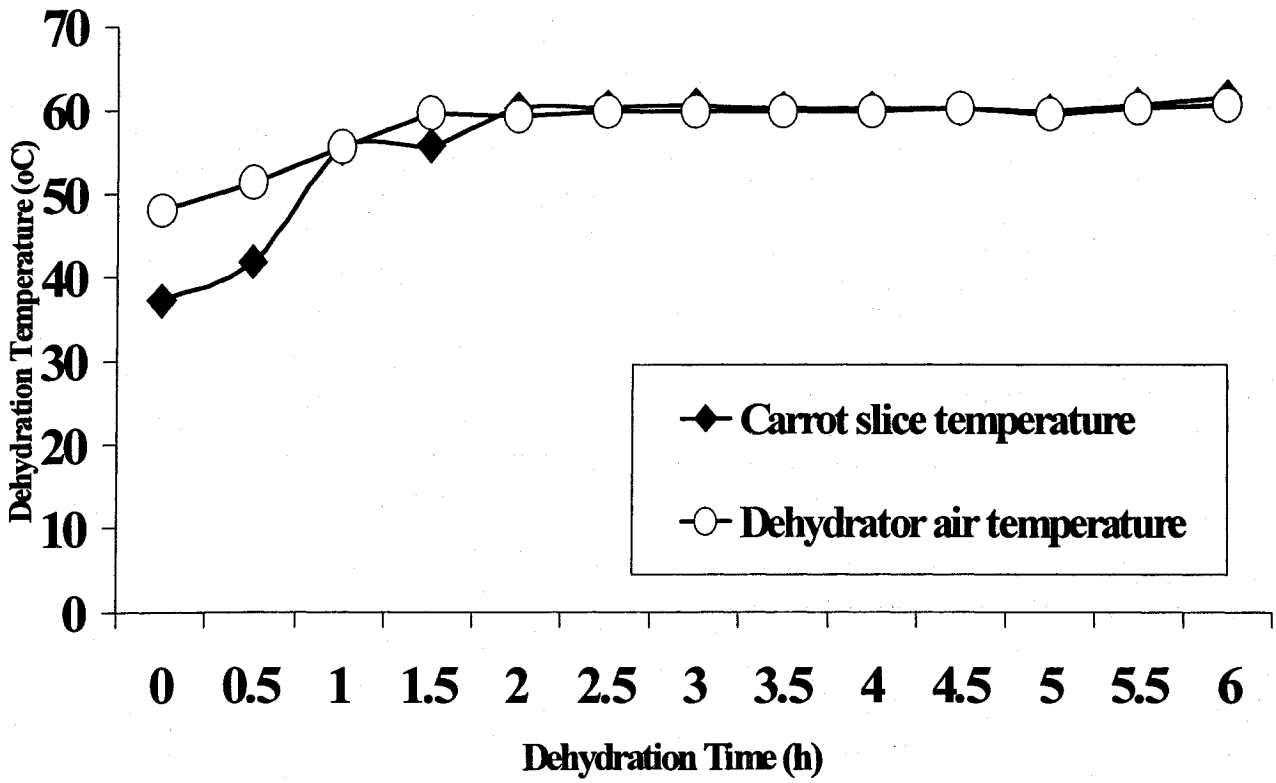

Figure 3.1. Mean temperature of Nantes carrot slices and dehydrator air during drying of carrot slices for up to 6 h following inoculation and various treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 3 min), water blanched (88°C, 3 min), or immersed in 3.23% NaCl (25°C, 5 min] and dried for 6 h, or dried for 6 h and oven heated (80°C, 15 min). Maximum dehydration temperature was approximately 60°C (140°F).

dehydration, the average temperature of the circulating air and carrot slices ranged from 59.2 to 60.5°C (Figure 3.1 and Table A3.1).

Effect of agar media. In general, populations of bacteria recovered with TSAP agar were higher than counts recovered on XLD agar during the 6 h of dehydration (Table 3.2), indicating that there were injured cells which were better recovered on TSAP. Injured cells that were able to grow on TSAP were probably unable to grow on XLD, a selective agar, due to the compositional differences in the two media (Boziaris et al., 1998; Hinton, 1999; Ho and Chou, 2001; Kirby and Davies, 1990).

Changes in bacterial counts caused by pre-drying treatment. *Salmonella* populations inoculated onto carrot slices were significantly ($P<0.05$) reduced immediately following steam blanching (88°C, 3 min), water blanching (88°C, 3 min) and dipping in 3.23% sodium chloride solution (25°C, 5 min), compared to the control (Table 3.2). The greatest reduction of bacterial populations (3.2-3.3 log CFU/g) was found on carrot slices treated with steam and water blanching. Perhaps treatment with steam and immersion in hot water (88°C) killed, injured and/or removed (washing effect) *Salmonella* cells from the carrot slices.

Immediately following immersion in 3.23% NaCl, reductions in populations were < 1.0 log CFU/g (Table 3.2). The sodium chloride solution used in the present study was probably not concentrated enough to effectively inhibit the survival of *Salmonella* and, therefore, may explain the small reductions of bacterial populations on carrot slices treated with immersion in 3.23% NaCl (Blackburn et al., 1997; Bower and Daeschel, 1999; Jay, 2000; Liao and Cook, 2001; Manas et al., 2001).

Changes in bacterial populations during dehydration, and after dehydration and oven heating. Dehydration of inoculated carrot slices at 60°C for 6 h without a pre-drying treatment

Table 3.2. Mean (log CFU/g[1]) bacterial (TSAP: tryptic soy agar with 0.1% pyruvate; XLD agar) populations (SD) on Nantes carrot slices inoculated with *Salmonella*, exposed to four pre-drying treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 3 min), water blanched (88°C, 3 min), or immersed in 3.23% NaCl (25°C, 5 min)] and dried for 6 h at 60°C (140°F), or dried for 6 h at 60°C and oven heated (80°C, 15 min).

Processing steps	Control[2]		Steam Blanch[3]		Water Blanch[4]		3.23% NaCl[5]	
	TSAP	XLD	TSAP	XLD	TSAP	XLD	TSAP	XLD
Before Inoculation[6]	2.34 (1.60)	1.60 (1.15)						
Following inoculation[7]	7.18^{Aax} (0.24)	6.96^{Aax} (0.28)	7.18^{Aax} (0.24)	6.96^{Aax} (0.28)	7.18^{Aax} (0.24)	6.96^{Aax} (0.28)	7.18^{Aax} (0.24)	6.96^{Aax} (0.28)
Following pre-treatment (0 h)	7.18^{Aax} (0.24)	6.96^{Aax} (0.28)	3.98^{Bcx} (0.52)	3.75^{Bcx} (0.53)	3.84^{Bcx} (0.60)	3.76^{Bcx} (0.30)	6.56^{Bbx} (0.16)	6.31^{Bbx} (0.18)
Dehydration (1.5 h)	6.58^{Bax} (0.22)	5.98^{Bay} (0.49)	3.89^{Bcx} (0.41)	3.61^{Bcx} (0.58)	4.23^{Bcx} (0.60)	3.52^{Bcy} (0.64)	5.81^{Cbx} (0.40)	5.29^{Cbx} (0.46)
Dehydration (3 h)	5.97^{Cax} (0.21)	5.38^{Cay} (0.32)	3.28^{Ccx} (0.24)	2.63^{CDby} (0.18)	3.23^{Ccx} (0.96)	2.91^{Cbx} (0.91)	5.43^{Cbx} (0.48)	4.90^{CDax} (0.69)
Dehydration (4.5 h)	5.82^{Cax} (0.21)	5.05^{CDay} (0.54)	3.83^{Bbx} (0.38)	2.89^{Cby} (0.62)	3.14^{Ccx} (0.43)	2.89^{Cbx} (1.02)	5.41^{Cax} (0.03)	4.61^{Day} (0.35)
Dehydration (6 h)	5.85^{Cax} (0.38)	5.00^{CDay} (0.54)	3.17^{Cdx} (0.45)	2.25^{Dcy} (0.51)	3.72^{Bcx} (0.48)	2.71^{Ccy} (0.83)	5.31^{Cbx} (0.63)	4.37^{Dby} (1.12)
Dehydration and Oven Heating[8]	5.49^{Cabx} (0.20)	4.55^{Daby} (0.26)						

[1] Means represent two samples in each of three replications (standard deviation of replicates) of log colony forming units (CFU/g): lowest detection limit by plating, 1.0 log CFU/g (LSD: 0.53 log CFU/g).
[2] Control, inoculated w/ no pre-treatment, or inoculated and steam blanched[3] (88°C, 3 min), water blanched[4] (88°C, 3 min), or immersed in 3.23% NaCl[5] (25°C, 5 min) before drying.
[6] It was determined that populations were not *Salmonella;* [7] Following inoculation (25°C, 30 min attachment time); [8] Following inoculation, dehydration (60°C, 6 h) and oven heating (80°C, 15 min).
A-E means with different superscripts within a column are significantly different ($P<0.05$); a-d means with different superscripts within a medium in the same row are significantly different ($P<0.05$).
x-y means with different superscripts within media of each treatment in a row are significantly different ($P<0.05$).

(control), or dehydration for 6 h followed by oven heated (80°C, 15 min), achieved similar bacterial reductions (1.7-2.4 log CFU/g) (Table 3.2). Reductions on steam blanched (4.0-4.7 log CFU/g) and water blanched (3.5-4.3 log CFU/g) slices were greater ($P<0.05$) than those on control and oven heated slices after 6 h of drying (Table 3.2). This could be attributed to the combined effect of the heat of blanching, low water activity and the heat of dehydration (Leistner and Gorris, 1995; Mackey and Derrick, 1982; Mattick et al., 2001).

Reductions of populations (1.9 to 2.6 CFU/g) on carrot slices immersed in 3.23% NaCl (25°C, 5 min) and dehydrated for 6 h at 60°C were similar to reductions on oven heated samples, and significantly ($P< 0.05$) less than those on steam and water blanched samples (Table 3.2). Many Cooperative Extension home food drying publications recommend treating carrot slices with a sodium chloride solution (up to 3.23%) before dehydration to improve quality and flavor (Brennand, 1994; Brewer, 1992; Swanson, 1995). Results of the present study, however, suggest that such a treatment may have no effect on *Salmonella* and, therefore, may not enhance the safety of home-dried carrot slices when pathogens are present.

Manas et al. (2001) investigated the effect of sodium chloride concentration on the heat resistance and recovery of *S.* typhimurium. Tryptic soy broth and agar with 6% yeast extract (TSBYE, TSAYE), and 0, 1, 2, 3, 4, or 5% added NaCl, were used as heating and recovery media, respectively. The survival of heated cells (58°C) was not significantly influenced by the presence of up to 5% NaCl in the recovery medium. Researchers explained that the inhibitory effect of NaCl was probably compensated for by the heat resistance of bacterial cells that developed during heat treatment. In some instances the addition of NaCl to the recovery medium even increased the probability of survival.

Changes in bacterial counts during storage. Bacterial populations on all samples continued to

decrease throughout aerobic storage at ambient temperature (25 ± 3°C) (Table 3.3). After 30 d of storage, populations ranged from 3.3 to 4.2 log CFU/g on carrot slices left untreated, or oven heated post-drying. Samples treated with immersion in 3.23% NaCl had bacterial populations of 2.1 to 3.5 log CFU/g after 6 h dehydration and 30 d storage. In general, there were fewer survivors on carrot slices treated with steam blanching (2.0-3.3 log CFU/g) and water blanching (1.7-3.0 log CFU/g) compared to all other treatments. The steam and water blanching procedures used in this study enhanced inactivation of *Salmonella* during dehydration and storage of carrot slices. However, it is important to note that *Salmonella* were still detectable by direct plating of all samples throughout 30 d of storage and, therefore, treatments may not sufficiently reduce food safety risk to home food preservers when the product is contaminated.

Changes in pH and water activity during dehydration and storage. The pH values of untreated Nantes carrot slices ranged from 4.84 ± 1.09 to 5.57 ± 0.52 throughout 6 h of dehydration and 30 d of storage, within the normal range for carrots (Tassou and Boziaris, 2002). Treatment with steam blanching, water blanching, immersion in 3.23% NaCl, or oven heating generally did not affect pH values (4.19 ± 1.92 to 5.60 ± 0.53) throughout dehydration and storage. The initial water activity of carrot slices ranged from 0.98 to 0.99 for all treatments (0 h). After 3 h of dehydration, all treatments had a water activity of <0.60, a level at which very few organisms are known to grow (Jay, 2000). Water activity values of all samples ranged from 0.26-0.31 immediately after 6 h of dehydration and ranged from 0.34-0.37 throughout 30 d of storage. Samples were stored in plastic bags (aerobically) at 25 ± 3°C and 30 ± 6% relative humidity; these conditions may have allowed the samples to gain some moisture during storage. Still, all samples had a water activity well below 0.60 throughout storage and, therefore, would be unlikely to support microbial growth (Chirife and del Pilar Buera, 1996).

Table 3.3. Mean (log CFU/g[1]) bacterial (TSAP: tryptic soy agar with 0.1% pyruvate; XLD agar) populations (SD) on Nantes carrot slices inoculated with *Salmonella*, exposed to four pre-drying treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 3 min), water blanched (88°C, 3 min), or immersed in 3.23% NaCl (25°C, 5 min)] and dried for 6 h at 60°C (140°F), or dried for 6 h at 60°C and oven heated (80°C, 15 min), and stored for up to 30 d at 25 ± 3°C.

	Control[2]		Steam Blanch[3]		Water Blanch[4]		3.23% NaCl[5]		Oven Heated[6]	
Storage Time	TSAP	XLD	TSAP	XLD	TSAP	XLD	TSAP	XLD	TSAP	XLD
0 d	5.85^{Aax} (0.38)	5.00^{Aay} (0.54)	3.17^{Abx} (0.45)	2.25^{Aby} (0.51)	3.72^{Abx} (0.48)	2.71^{ABby} (0.83)	5.31^{Aax} (0.63)	4.37^{Aay} (1.12)	5.49^{Aax} (0.20)	4.55^{Aay} (0.26)
5 d	5.63^{Aax} (0.31)	4.80^{Aay} (0.27)	3.42^{Abx} (0.93)	2.13^{Acy} (0.53)	3.95^{Abx} (0.47)	3.08^{Aby} (1.30)	5.03^{Aax} (0.08)	4.24^{Aay} (0.44)	5.22^{ABax} (0.19)	4.65^{Aay} (0.39)
15 d	4.57^{Bax} (0.52)	3.94^{Aay} (0.78)	3.78^{Aabx} (0.40)	1.70^{Aby} (0.33)	3.40^{Abx} (0.49)	1.91^{BCby} (0.52)	4.49^{Aabx} (0.06)	3.91^{Aax} (0.19)	4.61^{BCax} (0.17)	3.81^{ABay} (0.92)
30 d	4.15^{Bax} (0.13)	3.25^{Bay} (0.37)	3.25^{Abx} (0.27)	2.04^{Aby} (0.43)	2.98^{Abx} (0.67)	1.71^{Cby} (0.62)	3.51^{Babx} (0.11)	2.13^{Bby} (0.25)	4.12^{Cax} (0.13)	3.27^{Bay} (0.41)

[1] Means represent two samples in each of three replications (standard deviation of the replicates) of log colony forming units (CFU/g): lowest detection limit by plating, 0.87 log CFU/g (LSD: 0.87 log CFU/g).
[2] Control, inoculated w/ no pre-treatment, or inoculated and steam blanched[3] (88°C, 3 min), water blanched[4] (88°C, 3 min), immersed in 23% NaCl[5] (25°C, 5 min) before drying, or oven heated[6] (80°C, 15 min) after drying.
A-E means with different superscripts within a column are significantly different ($P<0.05$).
a-d means with different superscripts within a medium in the same row are significantly different ($P<0.05$).
x-y means with different superscripts within media of each treatment in a row are significantly different ($P<0.05$).

The expected level of *Salmonella* in dehydrated carrots is low; however, even extremely low numbers of cells adapted to the dry state have been shown to cause foodborne illness (CDC, 1995; Lehmacher et al., 1995; Mattick et al., 2001). Therefore, vegetable home-drying methods should be able to induce significant reductions of *Salmonella* contamination to help ensure the safety of the finished product. Cooperative Extension Services personnel across the United States recommend blanching or immersion in a sodium chloride solution before drying, or oven heating after drying, to enhance the quality and safety of dehydrated vegetable slices. However, current drying recommendations do not appear to effectively inactivate *Salmonella* during dehydration of carrot slices and, therefore, may not reduce the risk of foodborne illness when the product is contaminated. It is recommended that modified treatments be evaluated for their ability to inhibit or destroy *Salmonella* on home-dried carrots. Results of future studies will be useful in developing recommendations for home food drying.

CHAPTER IV

INACTIVATION OF *SALMONELLA* DURING DRYING AND STORAGE OF NANTES CARROT SLICES TREATED WITH STEAM, WATER OR ACID BLANCHING BEFORE DEHYDRATION

ABSTRACT

Documented outbreaks of human illness associated with consumption of dried foods have raised concerns about the effectiveness of home drying methods for pathogen destruction (Keene et al., 1997; Nummer et al., 2004; ProMED-mail, 2003). Dehydrated fruits and vegetables are minimally processed, and often consumed without further treatment that would normally inactivate pathogenic microorganisms. Salmonellae may pose a food safety risk from home-dried products such as carrot slices. This study evaluated the influence of treatments on inactivation of *Salmonella* during home-type dehydration (60°C, 6 h) and storage of carrot slices. Inoculated (five-strains, 7.8 log CFU/g) slices were subjected to the following treatments: 1) untreated control, 2) steam blanching (88°C, 10 min), 3) water blanching (88°C, 4 min), 4) blanching in a 0.105% citric acid solution (88°C, 4 min), or 5) blanching in a 0.21% citric acid solution (88°C, 4 min), dried for 6 h at 60°C (140°F), and stored for up to 30 d. Samples were analyzed by spread-plating on tryptic soy agar with 0.1% pyruvate (TSAP) and xylose lysine deoxycholate (XLD) agar for bacterial enumeration. Bacterial populations were reduced

by 3.8-4.1, 4.6-5.1 and 4.2-4.6 log CFU/g immediately following steam, water, or citric acid blanching, respectively. After treatment and 6 h of dehydration, total reductions were 1.6-1.7 (control), 4.0-5.0 (steam blanched), 4.1-4.6 (water blanched) and 4.9-5.4 (blanched in citric acid solution) log CFU/g. Surviving populations were higher ($P<0.05$) on control samples than all other samples after 6 h of drying. Populations continued to decrease throughout storage, but were still detectable by direct plating at 30 d on all samples except those blanched in 0.21% citric acid. By 15 d, populations on samples blanched in 0.21% citric acid were detectable only by enrichment. Blanching in steam, water and citric acid solutions enhanced inactivation of *Salmonella* during home-type drying of carrot slices. Blanching in acidic solutions resulted in the greatest reductions of populations after 6 h of drying and 30 d of storage. Results suggest that blanching carrot slices, particularly blanching in 0.21% citric acid before drying, should enhance destruction of potential *Salmonella* contamination during home-type dehydration and storage.

Introduction

The number of documented outbreaks of human illness associated with consumption of raw and minimally processed produce has increased in recent years (Bean et al., 1997; Beuchat, 2002; DeRoever, 1998). Improved surveillance systems, increased consumer consumption of fruits and vegetables, the emergence of new pathogens, and changes in production, processing and distribution practices are contributing factors (Beuchat, 2002). Produce may become contaminated with pathogenic organisms in the field and processing plant, as well as in the home due to improper handling, preparation and storage (Beuchat and Ryu, 1997; Fenlon et al., 1996; Ken-Ichi

et al., 1999; Thunberg et al., 2002). The most prevalent pathogen associated with produce is *Salmonella* (Thunberg et al., 2002), which has been isolated from fresh market samples of bean sprouts, cauliflower, cilantro, eggplant, endive, lettuce, melons, peppers, spinach and tomatoes (Beuchat, 1995; Beuchat, 2002; Johannessen et al., 2002; Tauxe et al., 1997; Thunberg et al., 2002). Furthermore, salmonellosis has been associated with consumption of raw or minimally processed produce including alfalfa sprouts, berries, cantaloupe, lettuce, tomatoes, watermelon, and unpastuerized apple and orange juices (Beuchat, 1995; Burnett and Beuchat, 2000; Liao and Cooke, 2001; PHLS, 2000a; PHLS, 2000b; Sagoo et al., 2003; Stafford, 2001).

Several researchers have evaluated the incidence of *Salmonella* contamination in fresh fruits and vegetables. For example, Ruiz et al. (1987) detected a 7.5% incidence of salmonellae in samples of vegetables from U.S. farms, wholesale markets and supermarkets. Wells and Butterfield (1997) collected 48 different fruits and vegetables from New Jersey supermarkets between 1992 and 1995 and found *Salmonella* contamination in 9-10% of samples. In 1999, the Food and Drug Administration (FDA/CFSAN, 2001) conducted a survey of imported fresh produce where the prevalence of *Salmonella* was 3.5%. Sagoo et al. (2003) tested retail bagged prepared ready-to-eat salad vegetables to determine their microbiological quality. Of the 3,852 samples tested, six (0.2%) were found to be of unacceptable quality because of the presence of *Salmonella*.

The prevalence of *Salmonella* in fresh and minimally processed produce is generally low; however, the pathogen can quickly grow to high populations and exist in the absence of obvious sensory defects (Berrang et al., 1989; Brackett, 1999). For

example, *Salmonella* was shown to survive and grow on the surface of intact tomatoes held at ambient temperature, and grow rapidly (reaching 8 log CFU/g within 24 h) in chopped ripe tomatoes at ambient temperature (Zhuang et al., 1995). Golden et al. (1993) found that *Salmonella* grew rapidly on fresh cut, ready-to-eat cantaloupe, honeydew and watermelon at 23°C; population increases of 5 to 7 log CFU/g were observed over a 24-hour storage period.

The efficacy of commercial decontamination processes in removing pathogens from fresh and minimally processed produce is generally unknown, but reductions are typically 1-2 log CFU/g (Sagoo et al., 2003; Seymour, 1999), causing concern about the microbiological safety of the product (Sagoo et al., 2003). The inability of conventional processing steps to effectively destroy pathogens has lead the Food and Drug Administration to propose that treatments of minimally processed commercial fresh juices should be capable of reducing pathogen loads by a minimum of 5 log CFU/ml (FDA, 1998).

Dehydration is a method of minimal processing that involves the addition of heat to food in order to evaporate inherent moisture and preserve the food from spoilage. The dehydration process often uses air to supply heat to a food product and carry moisture vapor away from the drying food (Desrosier and Desrosier, 1977). For the home gardener, dehydration is a way to preserve abundant crops for year-round use, prepare nutritious snacks, and create unique gifts (VanGarde and Woodburn, 1994). Dehydrated foods are also an important dietary component for military troops in need of light-weight, nonperishable meals.

DiPersio et al. (2005a) evaluated the influence of traditional home-type drying

treatments and aerobic storage (25°C, 30 d) on inactivation of *Salmonella* on carrot slices. Treatments were selected from recommendations made by Cooperative Extension Services for dehydrating vegetables and included steam or water blanching, immersion in NaCl solution, and post-drying oven heating (Brennand, 1994; Brewer, 1992; Dinstel, 1997; Hughes and Willenberg, 1999; Kendall and Allen, 1998; Mixon, 1998; Reynolds et al., 1993; Roberts and Cox, 1999; Swanson, 1995). After 6 h dehydration (60°C), bacterial reductions were 1.3-2.0 (control), 4.0-4.7 (steam blanched, 3 min), 3.5-4.3 (water blanched, 3 min), and 1.9-2.6 (3.23% NaCl immersion, 5 min) log CFU/g. Reductions on samples heated post-drying were 1.7-2.4 log CFU/g. All samples had populations >1.7 log CFU/g after 6 h of drying and 30 d of storage and, therefore, may pose a food safety risk. It was concluded that modified treatments were needed to enhance inactivation of *Salmonella* on dehydrated carrot slices.

United States Cooperative Extension Services personnel often recommend immersing fruits in an acidic solution before dehydration to maintain the color and quality of the product (Andress and Harrison, 1999; Archuleta, 2000; Brennand, 1994; Brewer, 1992; Kendall and Allen, 1994; Mixon, 1998; Taylor, 2001). Burnham et al. (2001) immersed inoculated apple slices in a 3.4% ascorbic acid solution (15 min) or steam blanched (3 min, 88.3°C) them prior to dehydration (6 h) at 57.2°C or 62.8°C. Control samples had a 2.9 log CFU/g reduction of *E. coli* O157:H7 following 6 h of dehydration. Steam blanching for 3 min had little effect on the destruction of bacteria, while immersion in 3.4% ascorbic acid induced a 5-log reduction during drying at both temperatures. In a similar study, DiPersio et al. (2003) evaluated whether treating inoculated Gala apple slices with acidic solutions enhanced inactivation of *Salmonella*

during dehydration and storage. After 6 h of dehydration at 60°C, populations on untreated or water treated slices were reduced by 2.7 to 4.2 log CFU/g. Populations were reduced by 3.8 to 5.7 log CFU/g on samples immersed in ascorbic acid (3.4%) or citric acid (0.21%) before dehydration. Bacteria were still detectable by direct plating after 28 d, except on ascorbic acid treated slices. Researchers concluded that immersion in acidic solutions, prior to dehydration, enhanced inactivation of *Salmonella* during dehydration and storage of Gala apple slices.

Among the United States Cooperative Extension recommended methods for drying carrots evaluated by DiPersio et al. (2005a), blanching prior to drying showed the most promise. It was speculated that longer blanching times and/or blanching in an acidic solution might enhance inactivation of *Salmonella* on dehydrated vegetables. The objective of this study was to determine whether longer blanching times or blanching in citric acid solutions, applied after inoculation of carrot slices, altered the survival of *Salmonella* during dehydration and storage.

Materials and Methods

Preparation of inoculum. The inoculum suspension consisted of *Salmonella* Typhimurium strains ATCC14028, ATCC700408, F530 isolated from an equine outbreak (provided by Dr. J.W. Foster, University of South Alabama, Mobile, AL), *S.* Agona isolated from alfalfa sprouts (provided by Dr. L.R. Beuchat, University of Georgia, Griffin, GA), and *S.* Copenhagen isolated from cattle hides. Inocula of each strain were prepared in tryptic soy broth (TSB, Difco, Becton Dickinson Co., Sparks, MD) by incubation at 35°C for 24 h. Cell suspensions of each strain were centrifuged (4629 × g, 4°C, 15 min) and suspended in 10 ml of phosphate buffered saline (PBS, pH 7.4; 0.2g

KH_2PO_4, 1.5g $Na_2HPO_4.7H_2O$, 8.0g NaCl and 0.2g KCl in 1 liter distilled water). The five suspensions of cells were combined to form a composite, which was re-centrifuged and re-suspended in 100 ml of PBS. Cell populations (7.8 log CFU/ml) in the composite inocula were determined by plating on tryptic soy agar (Difco) with 0.1% pyruvate (TSAP, Difco) and incubating for 24 h at 35°C.

Preparation and inoculation of carrot slices. Nantes variety carrots were purchased in July through September 2003 at a local grocery store, washed, peeled and sliced crosswise into 1/2 cm thick slices. Each sample consisted of 12 carrot slices that weighed approximately 18 ± 2g. Carrot slices, arranged on aluminum foil covered plastic trays, were inoculated with 0.25 ml of the *Salmonella* cell suspension which was spread onto the top surface of each slice and allowed to attach for 15 min at ambient temperature (approximately 25 ± 3°C). Under a laminar-flow hood, slices were then turned over and the other side inoculated following the same procedure. The mean inoculation level of carrot slices was 7.8 ± 0.3 log CFU/g.

Treatments. Procedures for steam blanching (88°C, 10 min) and water blanching (88°C, 4 min) used in the present study were derived from the longest times listed in existing home-drying recommendations (DiPersio et al., 2005a). These treatments were selected for the current study because of their possible antimicrobial effects as well as their ability to maintain the inherent characteristics of dried vegetables (color, texture) as noted in United States Cooperative Extension Service literature (Andress and Harrison, 1999; Archuleta, 2000; Brennand, 1994; Brewer, 1992; Herringshaw, 1997; Hughes and Willenberg, 1999; Kendall and Allen, 1998; Mixon, 1998; Penner et al., 1983; Roberts and Cox, 1999; Swanson, 1995; Taylor, 2001; Van Garde and Woodburn, 1994). The

amount of citric acid used was based on previous studies and United States Cooperative Extension fruit-drying recommendations for possible antimicrobial effects (Brewer, 1992; Burnham et al., 2001; DiPersio et al., 2004a; Kendall and Allen, 1994).

Following inoculation, carrot slices (110 slices per treatment; total weight ~1.3 kg) were left untreated, steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in a 0.105% food-grade citric acid solution (88°C, 4 min), or blanched in a 0.21% food-grade citric acid solution (88°C, 4 min). Sterilized distilled water was used to prepare all solutions to avoid contamination and other confounding factors. For blanching, 20-25 slices at a time were placed in a metal strainer, steam blanched or immersed in water or one of the citric acid solutions (1000 ml), drained for 2 min (not rinsed), placed in a single layer on dehydrator trays, dried for 6 h at 60°C (140°F) and stored in sterile plastic bags for up to 30 d at 25 ± 3°C and 30 ± 6% relative humidity (Digital Relative Humidity Meter, Control Company, Friendswood, TX).

Dehydration. Samples were dehydrated for 6 h at 60°C (140°F) in four American Harvest Gardenmaster dehydrators (model FD-1000, Nesco, Chaska, MN) simultaneously such that each of the three trays of each dehydrator contained carrot slices from each treatment as well as control slices. The dehydrators were preheated to 60°C (140°F) for approximately 30 min, trays were pre-loaded with inoculated carrot slices and inserted into the dehydrators, and the internal temperature of the slices was monitored throughout drying using thermocouples (Pico Technology, Cambridge, UK). Probes were inserted into each of 12 carrot slices, one slice from each tray of each dehydrator, and temperatures were recorded with real-time data recording software (Pico Technology). Circulating air temperature within the dehydrators was also monitored and recorded over

the 6 h drying period using four thermocouple probes (Pico Technology) inserted through the center opening of each dehydrator.

Sampling for analysis. For each treatment, one sample consisted of 12 carrot slices, one slice randomly selected from within the treatment slices on each of the three trays in each of the four dehydrators. Two samples per treatment were taken immediately after inoculation, after blanching (control samples were not treated) (0 h), at 1.5, 3, 4.5 and 6 h of drying, and on days 5, 15 and 30 of storage. Each 12-slice sample was aseptically transferred to an 18 oz sterile plastic bag (Nasco, Modesto, CA). The weight of each sample was recorded, maximum recovery diluent (MRD, 1.0g Bacto ™ Peptone and 8.5g sodium chloride in 1 L distilled water [Difco]) (Mattick et al., 2002) was added to the sample bag to total 21.5g and the bags were pummeled (IUL Instruments, Barcelona, Spain) for 120 sec at ambient temperature (25 ± 3°C). At each sampling interval, an extra slice from each treatment was taken and analyzed immediately for water activity.

Microbial analysis. Serial decimal dilutions were made in 9 ml of 0.1% sterile buffered peptone water (BPW, Difco). Each sample was surface plated on tryptic soy agar plus 0.1% pyruvate (TSAP, Difco) and xylose lysine deoxycholate (XLD, Difco) agar and incubated at 35°C for 24 h. All colonies for each agar were counted manually. Mean numbers of colonies were used to determine the colony forming units (CFU) per gram of carrot (CFU/g) and converted into log values. The formula used for converting the counts from plates into log CFU/g is: $W \times X \times (Y + Z)/Z$ where W is the average colony count from duplicate plates; X is the dilution factor; Y is the amount of MRD; and Z is the weight of carrot slices at each sampling time. When bacterial counts dropped below the detection limit, the *Salmonella* enrichment, isolation and identification methods outlined

in the Food and Drug Administration Bacteriological Analytical Manual (FDA, 2001) were followed.

Other analyses. The pH values of samples from all treatments and times of testing were determined after microbial analysis with a pH meter and a glass electrode (Denver Instruments, Arvada, CO). The water activity values of samples from all treatments at all sampling times were determined with a Rotronic water activity meter (model AwQUICK, Rotronic Instrument Corp., Huntington, NY).

Statistical analysis. The drying experiment was replicated three times and the data were analyzed using a 5 × 5 × 2 × 3 factorial design with 5 (number of treatments, including controls) × 5 (number of time intervals when samples were analyzed, i.e. after treatment (or 0 h), and at 1.5 h, 3 h, 4.5 h, and 6 h) × 2 (number of agar media) × 3 (number of replicates) factors. Storage data were analyzed using a 5 × 4 × 2 × 3 factorial design with 5 (number of treatments, including controls) × 4 (number of time intervals when samples were analyzed, i.e. after treatment and 6 h of drying (0 d), and at 5, 15 and 30 d of storage × 2 (number of agar media) × 3 (number of replicates) factors. For each replicate, the mean represented the average of two samples converted into log CFU/g. All data analyses were conducted with the Statistical Analysis System (SAS, 2000) for analysis of variance of main (fixed) effects and all interactions between fixed effects. When F-values were significant ($P<0.05$), least significant differences (LSD) in surviving bacterial population counts between treatments were determined using the ANOVA mixed model procedure of SAS. Means and standard deviations for pH and water activity data were calculated.

Results

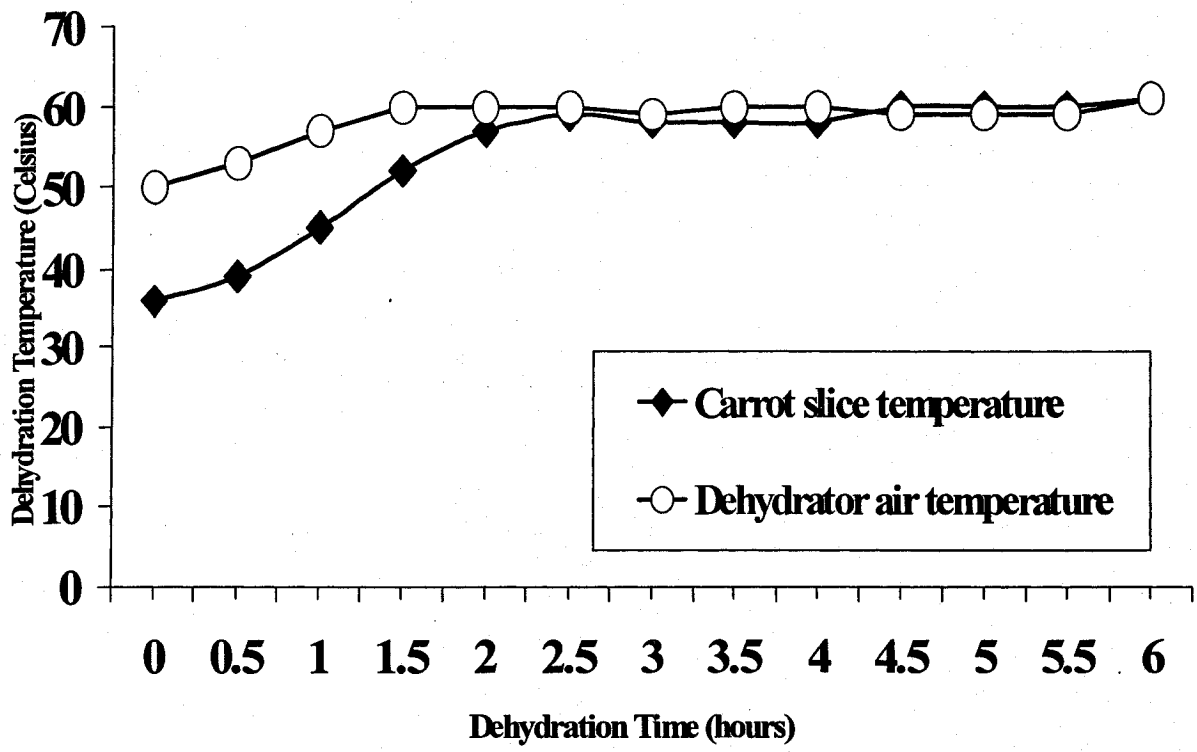

Figure 4.1. Mean temperature of Nantes carrot slices and dehydrator air during drying for up to 6 h following inoculation and various treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dried for 6 h. Maximum dehydration temperature was approximately 60°C (140°F).

Dehydrator air and carrot slice temperature. Insertion of loaded trays into the dehydrators reduced the mean circulating air temperature in the four dehydrators from 60°C to 50°C at 0 h of dehydration; the average temperature of the carrot slices at 0 h was 36°C (Figure 4.1 and table A4.1). The average temperature of the circulating air reached the target of 60°C by 1.5 h of dehydration and the average internal carrot slice temperature reached 60°C by 4.5 h of drying. From 2.5 to 6 h of dehydration, the average temperature of the circulating air and carrot slices ranged from 58 to 61°C (Figure 4.1 and Table A4.1).

Changes in pH and water activity during dehydration and storage. The pH values of untreated carrot slices (5.06 ± 0.31 to 5.49 ± 0.14) remained very near the normal range for carrots (5.4 to 5.8) (Tassou and Boziaris, 2002) throughout 6 h dehydration and 30 d storage (Figure 4.2 and Table A4.2). Steam and water blanching did not affect pH values (5.12 ± 0.41 to 5.46 ± 0.38). Carrot slices blanched in 0.105% and 0.21% citric acid (pH 3.08 ± 0.07 and 2.48 ± 0.2, respectively) had pH values of 4.28-4.47 and 3.87-4.12, respectively. The pH values of citric acid blanched carrot slices were significantly ($P<0.05$) lower than the values for all other treatments throughout dehydration and storage (Figure 4.2 and Table A4.2). The water activity of carrot slices was approximately 0.98 ± 0.01 at 0 h of dehydration, regardless of treatment. Water activity values of all samples ranged from 0.33 to 0.37 immediately following 6 h of dehydration, and from 0.29 to 0.38 throughout 30 d of storage (Table A4.3).

Changes in *Salmonella* populations following treatment and dehydration. Dehydration of inoculated carrot slices at 60°C for 6 h without a pre-drying treatment (control) resulted in bacterial reductions of 1.6 to 1.7 log CFU/g (Table 4.1). For the four

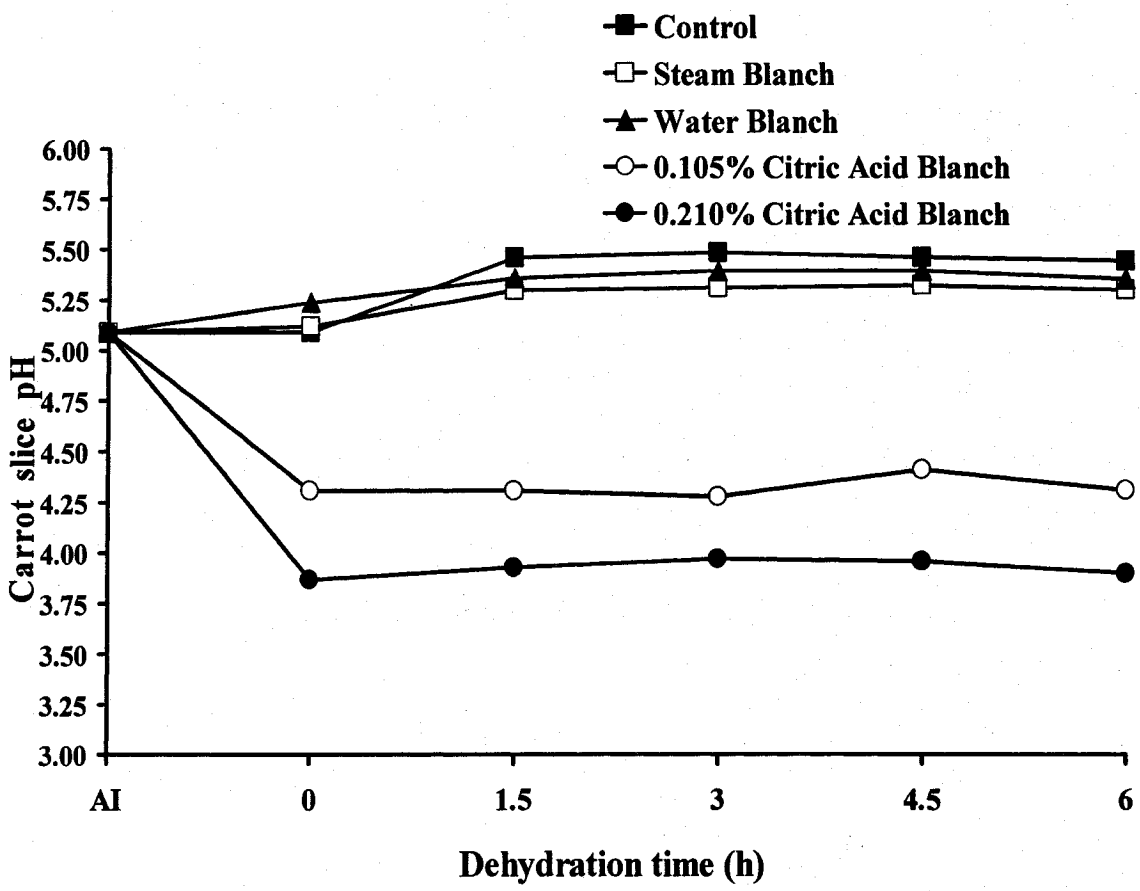

Figure 4.2. Mean pH of Nantes carrot slices during drying for up to 6 h following inoculation and various treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dried for 6 h at 60°C (140°F).

Table 4.1. Mean (log CFU/g[1]) bacterial (TSAP: tryptic soy agar with 0.1% pyruvate; XLD agar) populations (SD) on Nantes carrot slices inoculated with *Salmonella*, exposed to five pre-drying treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dried for 6 h at 60°C (140°F).

	Control[2]		Steam Blanch[3]		Water Blanch[4]		0.105% Citric Acid[5]		0.21% Citric Acid[6]	
Processing steps	TSAP	XLD	TSAP	XLD	TSAP	XLD	TSAP	XLD	TSAP	XLD
Following inoculation[7]	6.90^{Aax} (0.04)	6.70^{Aax} (0.36)	6.90^{Aax} (0.04)	6.70^{Aax} (0.36)	6.90^{Aax} (0.04)	6.70^{Aax} (0.36)	6.90^{Aax} (0.04)	6.70^{Aax} (0.36)	6.90^{Aax} (0.04)	6.70^{Aax} (0.36)
Following pre-treatment (0 h)	6.90^{Aax} (0.04)	6.70^{Aax} (0.36)	3.06^{Bbx} (0.55)	2.57^{Bbx} (0.50)	2.27^{Bbx} (1.18)	1.56^{Bcx} (0.95)	2.28^{Cbx} (1.00)	2.16^{Bbcx} (0.97)	2.72^{Bbx} (1.30)	2.40^{Bbcx} (1.08)
Dehydration (1.5 h)	5.76^{Bax} (0.88)	5.59^{Bax} (1.03)	3.28^{Bbx} (0.12)	2.65^{Bbx} (0.29)	3.07^{Bbx} (0.31)	2.38^{Bbcx} (0.28)	3.23^{Bbx} (0.20)	2.51^{Bbcx} (0.25)	2.13^{BCcx} (0.41)	1.71^{BCcx} (0.37)
Dehydration (3 h)	5.78^{Bax} (0.06)	5.04^{Bax} (0.05)	2.66^{Bbx} (0.45)	1.46^{Cbx} (0.46)	2.60^{Bbcx} (0.46)	1.72^{Bby} (0.36)	1.79^{Ccx} (0.39)	1.26^{Cbx} (0.10)	1.79^{Ccx} (0.18)	1.35^{Cbx} (0.23)
Dehydration (4.5 h)	5.53^{Bax} (0.08)	4.83^{Bax} (0.10)	3.18^{Bbx} (0.23)	2.00^{BCby} (0.75)	2.75^{Bbx} (0.33)	1.65^{Bby} (0.36)	1.45^{Ccx} (0.28)	1.50^{Cbx} (0.37)	1.47^{Ccx} (0.19)	1.24^{Cbx} (0.08)
Dehydration (6 h)	5.23^{Bax} (0.16)	5.07^{Bax} (0.08)	2.95^{Bbx} (0.54)	1.67^{Cby} (0.51)	2.82^{Bbcx} (0.23)	2.06^{Bbx} (0.71)	2.03^{Ccdx} (0.26)	1.69^{BCbx} (0.48)	1.82^{Cdx} (0.14)	1.27^{Cbx} (0.10)

[1] Means represent two samples in each of three replications (standard deviation of the replicates) of log colony forming units (CFU/g): lowest detection limit by plating, 1.1 log CFU/g. (LSD: 0.85 log CFU/g).

[2] Control, inoculated w/ no pre-treatment, or inoculated and steam blanched[3] (88°C, 10 min), water blanched[4] (88°C, 4 min), blanched in 0.105% citric acid[5] (88°C, 4 min), or blanched in 0.21% citric acid[6] (88°C, 4 min).

[7] Following inoculation (25°C, 30 min attachment time).

A-E means with different superscripts within a column are significantly different ($P<0.05$); a-d means with different superscripts within a medium in the same row are significantly different ($P<0.05$).

x-y means with different superscripts within media of each treatment in a row are significantly different ($P<0.05$).

blanching treatments, populations inoculated onto carrot slices were significantly ($P<0.05$) reduced (3.84-5.14 log CFU/g) immediately following blanching compared to the control (Table 4.1). After 6 h of drying, reductions on carrot slices treated with 10-min steam blanching (4.0-5.0 log CFU/g), 4-min water blanching (4.1-4.6 log CFU/g), 4-min blanching in 0.105% citric acid (4.9-5.0 log CFU/g) and 4-min blanching in 0.21% citric acid (5.1-5.4 log CFU/g) were greater ($P<0.05$) than those on control samples (Table 4.1).

Changes in *Salmonella* populations during storage. After 30 d of aerobic storage at ambient temperature (25 ± 3°C), *Salmonella* populations ranged from 2.69 to 3.82 log CFU/g on carrot slices left untreated and dehydrated for 6 h at 60°°C (Table 4.2). Samples treated with steam or water blanching before dehydration had bacterial populations of 1.20 to 2.13 log CFU/g after 30 d storage. In contrast, *Salmonella* populations on carrot slices blanched in acidic solutions before dehydration were detectable only after enrichment, except on samples blanched in 0.105% citric acid and plated on TSAP (Table 4.2).

Discussion

Illnesses associated with consumption of low moisture foods have raised concerns about the effectiveness of home drying methods to destroy pathogens if present (Bean et al., 1997; Beuchat, 2002; DeRoever, 1998; Keene et al., 1997; Nummer et al., 2004). The increased incidence of foodborne illness and the inability of conventional methods to effectively destroy pathogens have lead the Food and Drug Administration to propose that treatments of packaged juice and cider be capable of reducing pathogen loads by a minimum of 5 log CFU/ml (FDA, 1998). To date, there is no such standard for the

Table 4.2. Mean (log CFU/g[1]) bacterial (TSAP: tryptic soy agar with 0.1% pyruvate; XLD agar) populations (SD) on Nantes carrot slices inoculated with *Salmonella*, exposed to five pre-drying treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)], dried for 6 h at 60°C (140°F), and stored for up to 30 d at 25 ± 3°C.

	Control[2]		Steam Blanch[3]		Water Blanch[4]		0.105% Citric Acid[5]		0.21% Citric Acid[6]	
Storage Time	TSAP	XLD	TSAP	XLD	TSAP	XLD	TSAP	XLD	TSAP	XLD
0 d	5.23^{Aax} (0.16)	5.07^{Aax} (0.08)	2.95^{Abx} (0.54)	1.67^{Abcy} (0.51)	2.82^{Bbx} (0.23)	2.06^{ABby} (0.71)	2.03^{Acx} (0.26)	1.69^{Abcx} (0.48)	1.82^{Acx} (0.14)	1.27^{Acx} (0.10)
5 d	4.91^{ABax} (0.09)	4.15^{Bay} (0.48)	2.49^{ABcx} (0.19)	1.54^{Acy} (0.42)	3.75^{Abx} (0.65)	2.53^{Aby} (0.50)	1.95^{Acx} (0.12)	1.35^{Acx} (0.12)	2.19^{Acx} (0.37)	1.35^{Acy} (0.08)
15 d	4.37^{BCax} (0.24)	3.22^{Cay} (0.31)	2.83^{Abx} (0.42)	1.53^{Aby} (0.54)	2.02^{Ccx} (0.48)	1.58^{Bcbx} (0.44)	1.88^{ABcx} (0.95)	1.50^{Abx} (0.52)	<1.10*	<1.10*
30 d	3.82^{Cax} (0.33)	2.69^{Cay} (0.46)	2.13^{Bbx} (0.26)	1.20^{Aby} (0.10)	1.96^{Cbx} (0.56)	1.37^{Cbx} (0.17)	1.28^{Bc} (0.03)	<1.10*	<1.10*	<1.10*

[1] Means represent two samples in each of three replications (standard deviation of the replicates) of log colony forming units (CFU/g): lowest detection limit by plating, 1.1 log. CFU/g (LSD: 0.61 log CFU/g).
[2] Control, inoculated w/ no pre-treatment, or inoculated and steam blanched[3] (88°C, 10 min), water blanched[4] (88°C, 4 min), blanched in 0.105% citric acid[5] (88°C, 4 min), or blanched in 0.21% citric acid[6] (88°C, 4 min).
A-E means with different superscripts within a column are significantly different (P<0.05); a-d means with different superscripts within a medium in the same row are significantly different (P<0.05).
x-y means with different superscripts within media of each treatment in a row are significantly different (P<0.05).
* Detectable by enrichment only.

processing of dehydrated vegetables and, therefore, a 5 log CFU/g reduction of pathogen populations was used as a guideline for the current study.

Changes in pH and water activity during dehydration and storage. The pH values of untreated Nantes carrot slices remained within the normal range for carrots throughout 6 h of dehydration and 30 d of storage (Tassou and Boziaris, 2002) (Figure 4.2 and Table A4.2). Steam and water blanching did not affect pH values, while blanching in citric acid solutions significantly ($P<0.05$) lowered the pH of samples throughout dehydration and storage (Figure 4.2 and Table A4.2). The initial water activity of carrot slices ranged from 0.98 to 0.99 for all treatments (0 h) (Table A4.3). After 3 h dehydration and throughout 30 d storage, all samples had a water activity of <0.60, the level at which very few organisms are able to grow (Table A4.3) (Jay, 2000). Water activity values of all samples increased from 0.26-0.31 immediately after 6 h of dehydration, to 0.34-0.37 throughout 30 d of storage. Carrot slices were stored in plastic bags (aerobically) at 25 ± 3°C and 30 ± 6% relative humidity; conditions which may have allowed samples to gain moisture during storage. Still, all samples had a water activity well below 0.60 throughout storage and, therefore, would be unlikely to support microbial growth (Chirife and del Pilar Buera, 1996).

Effect of agar media. *Salmonella* populations recovered with TSAP agar were generally higher than counts recovered on XLD agar during the 6 h of dehydration (Table 4.1). Differences in cell counts between media indicate potential presence of injured cells (Boziaris et al., 1998; Hinton, 1999; Kirby and Davies, 1990).

Changes in *Salmonella* populations caused by treatments. *Salmonella* populations were significantly ($P<0.05$) reduced immediately following blanching compared to the

control (Table 4.1). In fact, blanching induced 3.9 to 5.1 log CFU/g reductions in bacterial populations before the application of dehydration. Wuytack et al. (2002) studied the inactivation of *Salmonella* by heat and indicated that heat is known to cause cell membrane damage, protein denaturation and the denaturation of nucleic acids. Most likely, all of these targets are hit simultaneously to cause sublethal and lethal damage to bacterial cells. In the present study, the prolonged heat of blanching in steam (10 min, 88°C), or immersion in water or a citric acid solution (4 min, 88°C) may have killed, inactivated, and/or removed (washing effect) *Salmonella* cells from the carrot slices.

Blanching carrot slices in the citric acid solutions did not enhance reductions in *Salmonella* populations immediately following blanching compared to water blanching, but generally improved reductions during drying and storage. Temperature and pH have been shown to interact to form barriers to the survival of certain pathogens (Uljas and Ingham, 1999). In the present study, citric acid was added to blanching water to reduce pH from 6.70-6.80 to 2.48-3.08, thus reducing the pH of carrot slices blanched in the acidic solutions (Figure 4.2). In a low pH environment, citric acid molecules are able to cross bacterial cell membranes, dissociate into charged ions, and accumulate within the cytoplasm (Booth and Kroll, 1998). Acidification of the cytoplasm prompts a stress response which hinders metabolic processes and depletes energy reserves needed for survival and growth (Bracey et al., 1998). Furthermore, treatments that are known to cause high levels of sublethal injury (heat) are also known to act synergistically with other factors such as low pH (Alpas et al., 2000; Casadei et al., 2001; Wuytack et al., 2002). In the present study, high temperature and low pH may have acted synergistically to inhibit the survival of *Salmonella* cells inoculated onto carrot slices blanched in

0.105% or 0.21% citric acid.

Changes in *Salmonella* populations during dehydration. Dehydration (60°C, 6 h) of inoculated carrot slices without a pre-drying treatment (control) achieved bacterial reductions of 1.6 to 1.7 log CFU/g (Table 4.2). Reductions on 10-min steam blanched (4.0-5.0 log CFU/g) and 4-min water blanched (4.1-4.6 log CFU/g) slices were greater ($P<0.05$) than those on control samples after 6 h of drying (Table 4.2). DiPersio et al. (2005a) found that steam blanching (88°C, 4 min) or water blanching (88°C, 3 min) inoculated carrot slices before dehydration (60°C, 6 h) induced similar reductions (3.5-4.7 log CFU/g). Results could be attributed to the combined effect of the heat of blanching, low water activity and the heat of dehydration (Leistner and Gorris, 1995; Mackey and Derrick, 1982; Mattick et al., 2001). Samples blanched in 0.105% or 0.21% citric acid before drying had bacterial reductions of >5log CFU/g, except on carrot slices blanched in 0.105% citric acid and plated on TSAP. In general, blanching carrot slices in citric acid solutions before dehydration improved inactivation of *Salmonella* during dehydration compared to all other treatments. Similarly, Calicioglu et al. (2003) reported that a 5% acetic acid dip (pH 2.50), applied before marination of inoculated beef strips, improved inactivation of *Salmonella* during dehydration compared to controls.

Changes in *Salmonella* populations during storage. Bacterial populations continued to slowly decline throughout aerobic storage at ambient temperature (25 ± 3°C) for all samples. However, populations on untreated carrot slices were still >2.6 log CFU/g after 30 d of storage and, therefore, could present a food safety risk. In 1993, an outbreak of salmonellosis was traced to contaminated paprika and paprika-powdered potato chips. The infective dose was estimated at 4 to 45 cells, indicating that even very low numbers

of *Salmonella* cells adapted to a low water activity may cause illness (Lehmacher et al., 1995). Steam and water blanching enhanced inactivation of *Salmonella* during dehydration and storage of carrot slices; however, populations were still detectable by direct plating after 30 d of storage. In contrast, populations were undetectable by direct plating on carrot slices blanched in citric acid and stored for 30 d, except on samples blanched in 0.105% citric acid and plated on TSAP. Nevertheless, carrot slices blanched in 0.21% citric acid had bacterial reductions of >5 log CFU/g after 6 h dehydration, and all acid blanched samples achieved this level of reduction by 15 d of storage.

Salmonellae may pose a food safety risk from home-dried vegetables that undergo processing steps (handling, washing, cutting) that could introduce pathogens and/or enhance their growth (Brackett, 1999; Beuchat, 2002; Beuchat and Ryu, 1997; Thunberg et al., 2002). Compared to traditional home-drying methods, the blanching treatments used in the current study were more effective in reducing *Salmonella* populations on inoculated carrot slices immediately after treatment, and throughout dehydration and storage. More research is needed to understand *Salmonella* survival in dehydrated vegetables, and to develop pathogen reduction guidelines for home-dried produce. Furthermore, research is needed to evaluate the sensory characteristics of vegetables blanched in organic acid solutions before dehydration.

CHAPTER V

INFLUENCE OF BLANCHING TREATMENTS ON *SALMONELLA* DURING HOME-TYPE DEHYDRATION AND STORAGE OF POTATO SLICES

ABSTRACT

Recommended drying treatments may not enhance destruction of pathogens that could be present on home-dried foods. This study evaluated the influence of traditional and modified treatments on *Salmonella* during home-type dehydration (60°C, 6 h) and storage of potato slices. Inoculated (five-strains, 8.4 log CFU/g) potato slices were: 1) left untreated, or treated with 2) steam blanching (88°C, 10 min), 3) water blanching (88°C, 4 min), 4) 0.105% citric acid blanching (88°C, 4 min), or 5) 0.21% citric acid blanching (88°C, 4 min), dried (6 h, 60°C), and aerobically stored for up to 30 d. Samples were diluted and plated onto tryptic soy agar with 0.1% pyruvate (TSAP) and xylose lysine doxycholate (XLD) agar. *Salmonella* populations were reduced by 4.5-4.8 and >5.4 log CFU/g immediately following steam and water blanching, respectively. Populations were below the detection limit (0.80 log CFU/g) immediately following acid blanching, except for samples blanched in 0.105% citric acid and recovered on TSAP. After treatment and dehydration, *Salmonella* reductions on blanched potato slices (5.3-5.4 log CFU/g) were significantly ($P<0.05$) greater than those on control samples (1.9-2.7 log CFU/g). Populations on all samples continued to decrease throughout 30 d of storage but still ranged from 3.14 to 3.92 log CFU/g on control samples. In comparison, bacterial

populations on blanched samples were undetectable by direct plating following 30 d of storage (regardless of blanching method). It was concluded that blanching treatments used in this study improved the effectiveness of drying in inactivating *Salmonella* inoculated onto potato slices and, therefore, may enhance the safety of the product when contamination occurs.

Introduction

An increasing association between minimally processed produce and foodborne infection has lead to concerns about the microbial contamination of these products (Beuchat, 2002; Natvig et al., 2002; Tauxe et al., 1997). *Salmonella* is the most prevalent pathogen associated with produce and has been isolated from fresh cauliflower, cilantro, eggplant, endive, mangoes, melons, peppers, spinach, sprouts and tomatoes (Beuchat, 2002; Garrett et al., 2003; Sivapalasingam et al., 2003; Thunberg et al., 2002). Minimally processed fruits and vegetables seem to be associated with foodborne illness more frequently than fresh, whole produce (Brackett, 1999; Conway et al., 2000; Garrett et al., 2003). This may be because the peel or rind provides a physical and chemical barrier which prevents the establishment of microbes on edible surfaces (CDC, 1990; Conway et al., 2000). This barrier is removed during processing and may result in the establishment of pathogen cells, leading to increased risk of foodborne illness (Conway et al., 2000; Garrett et al., 2003; Ken-Ichi et al., 1999). Salmonellosis has been associated with consumption of improperly processed and/or mishandled apple cider, cantaloupe, cilantro, lettuce, mangoes, orange juice, potatoes, tomatoes and watermelon (Burnett and Beuchat, 2000; Garrett et al., 2003; Liao and Cooke, 2001; PHLS, 2000; Sagoo et al., 2003; Sivapalasingam et al., 2003; Sivapalasingam et al., 2004; Stafford, 2001). In fact,

one of the largest outbreaks of foodborne salmonellosis ever reported to the Centers for Disease Control and Prevention (CDC), affecting an estimated 3,400 people, occurred due to the improper handling of potato salad (Horwitz et al., 1977).

Dried foods were traditionally considered unlikely sources of foodborne illness; however, dehydrated vegetables such as mushrooms and asparagus have long been known to be contaminated occasionally with *Salmonella* (Lehmacher et al., 1995). Furthermore, salmonellosis outbreaks have been associated with consumption of low moisture foods such as meat jerky, potato chips, a chip-type snack and chocolate (CDC, 1995a; Eidson et al., 2000; Greenwood and Hooper, 1983; Kapperud et al., 1990; Keene et al., 1997; Killalea et al., 1996). In New Mexico between 1966 and 1995, six gastroenteritis outbreaks were associated with ingestion of meat jerky contaminated with *Salmonella* and resulted in over 100 illnesses (Eidson et al., 2000). In Germany, an international outbreak of salmonellosis, resulting in an estimated 1000 illnesses, was traced to contaminated paprika-powdered potato chips (Lehmacher et al., 1995). As few as 4 cells per gram were found in the chips prompting investigators to conclude that even very low numbers of *Salmonella* cells adapted to a limited water system may cause illness (Mackey and Derrick, 1982; Lehmacher et al., 1995).

Unlike most dehydrated vegetables which are added to soups, stews, or otherwise cooked before consumption, dehydrated potato slices are often consumed without further processing as potato chips. United States Cooperative Extension Services recommend steam blanching, water blanching or immersion in a salt solution before drying, or oven heating after drying, to inhibit browning and/or extend the shelf life of home-dried potato slices (Brennand, 1994; Dinstel, 1997; Herringshaw, 1997; Hughes and Willenberg,

1999; Kendall and Allen, 1998; Reynolds et al., 1993; Roberts and Cox, 1999; Swanson, 1995). Although these treatments improve color and quality, DiPersio et al. (2005a) found that some commonly recommended treatments may not improve the safety of home-dried vegetables. DiPersio et al. (2005a) evaluated the influence of steam blanching (3 min), water blanching (3 min), or immersion in a 3.23% salt solution (5 min) before drying, or oven heating (80°C, 15 min) after drying, on inactivation of *Salmonella* (7.8 log CFU/g) during dehydration and storage of carrot slices. After 6 h of dehydration at 60°C, bacterial reductions were 1.3-2.0 (control), 4.0-4.7 (steam blanched), 3.5-4.3 (water blanched) and 1.9-2.6 (3.23% NaCl) log CFU/g. Reductions on samples heated after drying were 1.7-2.4 log CFU/g. All samples had populations >1.7 log CFU/g after 6 h of drying and 30 d of storage. It was concluded that modified treatments, including extended blanching times, were needed to enhance inactivation of *Salmonella* in dehydrated vegetable slices.

In contrast to vegetables, fruits are traditionally immersed in organic acid solutions before home-type dehydration to preserve the inherent characteristics of the final product (Andress and Harrison, 1999; Archuleta, 2000; Brennand, 1994; Brewer, 1992; Kendall and Allen, 1994; Mixon, 1998; Taylor, 2001). DiPersio et al. (2003) reported that treating inoculated Gala apple slices with acidic solutions enhanced inactivation of *Salmonella* during dehydration and storage. Populations on untreated or water treated samples were reduced by 2.7 to 4.2 log CFU/g following dehydration (60°°C, 6 h). In comparison, reductions were 3.8 to 5.7 log CFU/g on slices immersed in ascorbic acid (3.4%, 25 ± 3°C) or citric acid (0.21%, 25 ± 3°C), then dried (60°C, 6 h). *Salmonella* populations were detectable by direct plating after 28 d of storage, except on

ascorbic acid treated slices.

Outbreak investigations emphasize the risk for foodborne illness associated with consumption of home-dried foods (Keene et al., 1997). Cooperative Extension Services have long provided guidelines to consumers on how to dry foods at home, yet these guidelines have been imprecise and based on anecdotal experience rather than scientific documentation. Furthermore, some commonly recommended methods for home-drying vegetables did not reduce the risk of *Salmonella* survival and, therefore, may not enhance the safety of the finished product if contamination occurs (DiPersio et al., 2005a). Among recommended methods for home-drying produce evaluated by DiPersio et al. (2003; 2004a; 2005a), blanching and immersion in acidic solutions prior to dehydration showed the most promise. The objective of the present study was to evaluate the influence of extended steam blanching, water blanching and blanching in acidic solutions on inactivation of *Salmonella* during preparation, home-type dehydration (60°C, 6 h) and storage of Russet potato slices.

Materials and Methods

Bacterial strains. Microorganisms used in this study included *Salmonella* Typhimurium strains ATCC14028, ATCC700408, F530 isolated from an equine outbreak (provided by Dr. J.W. Foster, University of South Alabama, Mobile, AL), *S.* Agona isolated from alfalfa sprouts (provided by Dr. L.R. Beuchat, University of Georgia, Griffin, GA), and *S.* Copenhagen (isolated from cattle hides). All strains were available as frozen (-30°C) cultures in tryptic soy broth (TSB, Difco, Becton Dickinson Co., Sparks, MD) plus 20% glycerol and activated by transferring 0.05 ml of stock culture in 10 ml TSB at 35°C overnight. The five strains were subcultured twice (35°C, 24 h), then combined to form a

composite. Composite cell populations (8.4 log CFU/ml) were determined by plating on tryptic soy agar with 0.1% pyruvate (TSAP, Difco) and incubating for 24 h at 35°C.

Preparation and inoculation of samples. White Russet potatoes were obtained from a local supermarket in the late spring and summer of 2004, washed, peeled and sliced crosswise into 1/2 cm thick slices. Each sample consisted of two potato slices that together weighed approximately 11 ± 3g. Slices were placed on plastic trays and inoculated under a laminar-flow hood. Portions of 0.25 ml of the *Salmonella* inoculum were placed on the upper surface of each slice and allowed to attach for 15 min at ambient temperature (approximately 25 ± 3°C). The slices were then flipped over and the other side was inoculated following the same procedure. The resulting level of inoculum was approximately 8.4 log CFU/g.

Treatments. The steam blanching time (10 min) used in the current study was extended from the longest time (9 min) recommended for steam blanching potato slices 1/8 to 1/4 inch thick (approximately 1/2 cm thick) (Archuleta, 2000). The water blanching (88°C, 4 min) method used was derived from the time most often listed for drying 1/8 to 1/4 inch thick vegetable slices (approximately 1/2 cm). Recommendations for water blanching potato slices (approximately 1/2 cm thick) ranged from 4 to 7 min (Archuleta, 2000; Brennand, 1994; Swanson, 1995). Treatments were chosen for their possible antimicrobial effects as well as their ability to maintain the color and quality of dehydrated potato slices (Andress and Harrison, 1999; Archuleta, 2000; Brennand, 1994; Brewer, 1992; Dinstel, 1997; Herringshaw, 1997; Hughes and Willenberg, 1999; Kendall and Allen, 1998; Mixon, 2004; Penner et al., 1983; Reynolds et al., 1993; Roberts and Cox, 1999; Swanson, 1995; Taylor, 2001; Van Garde and Woodburn, 1994). The

concentrations of the citric acid solutions were derived from previous studies and United States Cooperative Extension fruit-drying recommendations (Brewer, 1992; Burnham et al., 2001; DiPersio et al., 2003; DiPersio et al., 2004; Kendall and Allen, 1994). Citric acid was chosen because it acts as an antibrowning and antimicrobial agent (Giannuzzi and Zaritzky, 1992), and is regarded as GRAS by the FDA (CFR, 2001).

Inoculated potato slices (40 slices per treatment; ~2.4 kg) were left untreated (control), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min), dried (6 h, 60°C), and aerobically stored for up to 30 d. Sterilized distilled water was used to prepare all solutions to avoid contamination, pH differences and other confounding factors. For blanching, potato slices (15 at a time) were arranged in a 1 L metal strainer, then held for 10 min over a 4 L kettle of boiling water (steam blanched), or immersed for 4 min in a 4 L kettle of boiling water or citric acid solution (88°C). The strainers were then removed and allowed to drain for 2 min (not rinsed). The drained slices were allowed to cool for 10 min (to permit handling), then arranged in single layers on dehydrator trays, dried for 6 h at 60°C (140°F) and stored in sterile plastic bags for up to 30 d at 25 ± 3°C and 30 ± 6% relative humidity (Digital Relative Humidity Meter, Control Company, Friendswood, TX).

Dehydration. All samples were dehydrated for 6 h at 60°C (140°F) in four home-type dehydrators (American Harvest Gardenmaster, model FD-1000, Nesco, Chaska, MN) simultaneously such that all three trays of each dehydrator contained samples from each treatment (including controls). The dehydrators were preheated to 60°C (140°F) for approximately 30 min then loaded with trays containing the inoculated and treated potato

slices. Circulating air and potato slice temperatures were monitored during drying using thermocouple probes and real-time data recording software (Pico Technology, Cambridge, UK) as described by DiPersio et al. (2003).

Sampling for analysis. For each treatment, one sample consisted of 2 potato slices, one slice randomly selected from within the treatment slices on each of the three trays in each of the four dehydrators. Two, 2-slice samples per treatment were aseptically transferred into sterile plastic bags at each sampling interval: immediately after inoculation, after blanching (control samples were not blanched) (0 h), at 1.5, 3, 4.5 and 6 h of drying, and on days 5, 15 and 30 of storage. The weight of each sample was recorded, maximum recovery diluent (MRD, 1.0g Bacto ™ Peptone and 8.5g sodium chloride in 1 L distilled water [Difco]) (Mattick et al., 2002) was added to the sample bag to total 21.5g, and the samples were pummeled (IUL Instruments, Barcelona, Spain) for 120 sec at ambient temperature (25 ± 3°C). The pH was measured from samples used for microbial analysis using a digital pH meter with a glass pH electrode (Denver Instruments, Arvada, CO). At each sampling interval, an extra slice was taken from each treatment and immediately analyzed for water activity with a water activity meter (model AwQUICK, Rotronic Instrument Corp., Huntington, NY).

Microbial analysis. Serial decimal dilutions were made using 9 ml of 0.1% sterile buffered peptone water (BPW, Dofco); 0.1 ml portions were surface plated onto each of duplicate plates of tryptic soy agar plus 0.1% pyruvate (TSAP, Difco) and xylose lysine deoxycholate (XLD, Difco) agar, and plates were incubated at 35°C for 24 h. Mean numbers of colonies were used to determine the colony forming units (CFU) per gram of potato (CFU/g) and converted into log values. The formula used for converting the counts

from plates into log CFU/g is: W × X × (Y + Z)/Z where W is the average colony count from duplicate plates; X is the dilution factor; Y is the amount of MRD; and Z is the weight of potato slices at each sampling time. When numbers of bacteria dropped below the detection limit by direct plating, the *Salmonella* enrichment, isolation and identification methods outlined in the FDA Bacteriological Analytical Manual (FDA, 2001) were followed.

Statistical analysis. Three independent replicates of the study were conducted. The microbiological data were analyzed using a 5 × 5 × 2 × 3 factorial design with 5 (number of treatments, including controls) × 5 (number of time intervals when samples were analyzed, i.e. after treatment (or 0 h), and at 1.5 h, 3 h, 4.5 h, and 6 h) × 2 (number of agar media) × 3 (number of replicates) factors. Storage data were analyzed using a 5 × 4 × 2 × 3 factorial design with 5 (number of treatments, including controls) × 4 (number of time intervals when samples were analyzed, i.e. after treatment and 6 h of drying (0 d), and at 5, 15 and 30 d of storage × 2 (number of agar media) × 3 (number of replicates) factors. For each replicate, the mean represented the average of two samples converted into log CFU/g. All data analyses were conducted with the Statistical Analysis System (SAS Institute version 9.1, Cary, NC) for analysis of variance of main (fixed) effects and all interactions between fixed effects. When F-values were significant ($P<0.05$), least significant differences (LSD) in surviving bacterial population counts between treatments were determined using the ANOVA mixed model procedure of SAS. Means and standard deviations for pH and water activity data were calculated.

Results and Discussion

Dehydrator and sample temperature. Changes in dehydrator air temperature and potato slice temperatures were recorded throughout dehydration (Figure 5.1 and Table A5.1). Placement of loaded trays into the preheated dehydrators reduced the mean circulating air temperature from 60°C to 45°C at 0 h of dehydration. Potato slices were cooled (10 min) to permit handling and, therefore, the average temperature of slices was 31°C at 0 h of dehydration (Figure 5.1 and Table A5.1). The average circulating air temperature and internal potato slice temperature reached the target of 60°C by 1.5 and 2 h of dehydration, respectively. From 2 to 6 h of drying, the average temperature of the circulating air and potato slices ranged from 60 to 62°C (Figure 5.1 and Table A5.1).

Effect of media. Consistently higher numbers of *Salmonella* were recovered on TSAP than on XLD, regardless of treatment, indicating that some cells were stressed and not able to resuscitate on the selective agar (Table 5.1).

pH and water activity during dehydration and storage. Untreated (control) samples had pH values (5.66 ± 0.23) within the normal range for potatoes (pH 5.40 to 5.90) (FDA/CFSAN, 2003) throughout 6 h of dehydration and 30 d of storage (Figure 5.2 and Table A5.2). Steam and water blanched potato slices had pH values (5.42 ± 0.29) similar to controls throughout dehydration and storage. Samples blanched in 0.105% (pH 3.08 ± 0.07) or 0.21% (pH 2.48 ± 0.21) citric acid had pH values (4.95 ± 0.55 and 4.90 ± 0.63, respectively) that were generally lower than all other values throughout dehydration, and significantly ($P<0.05$) lower than all other values throughout dehydration and storage.

Regardless of treatment, all samples had an initial water activity of 0.98 ± 0.01 at 0 h of dehydration. Water activity values ranged from 0.16 to 0.44 at 3 h of dehydration

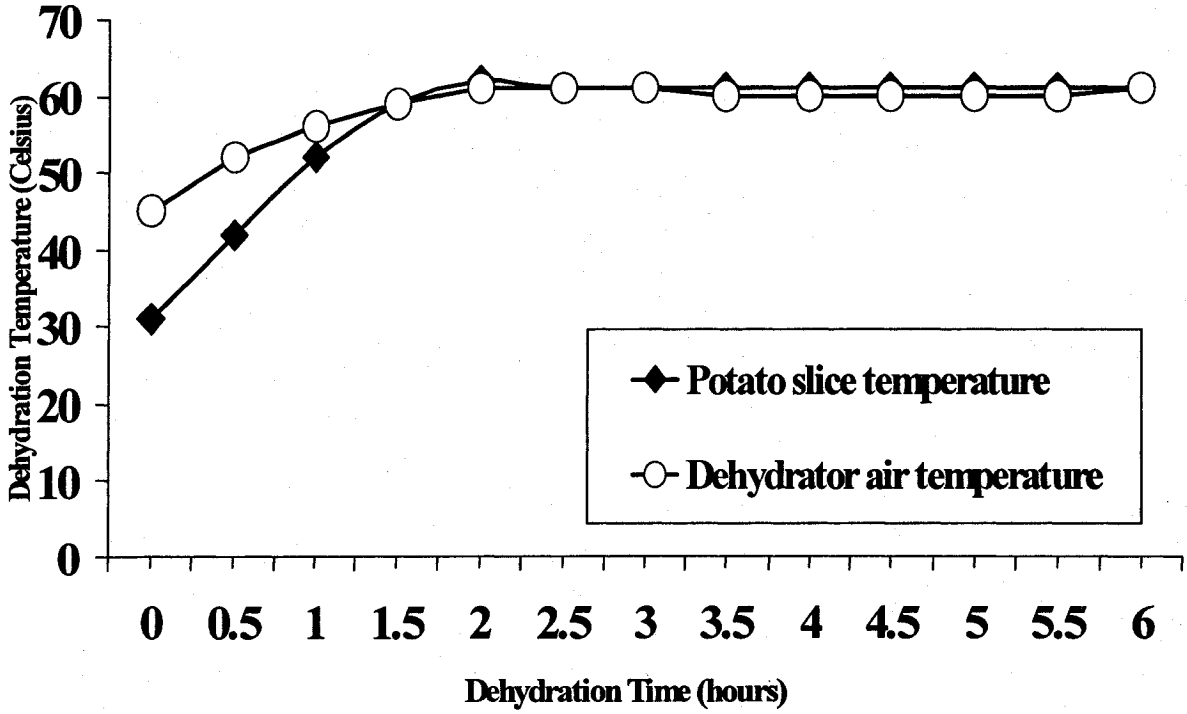

Figure 5.1. Mean temperature of Russet potato slices and dehydrator air during drying for up to 6 h following inoculation and various treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dried for 6 h. Maximum dehydration temperature was approximately 60°C (140°F).

Table 5.1. Mean (log CFU/g[1]) bacterial (TSAP: tryptic soy agar with 0.1% pyruvate; XLD agar) populations (SD) on Russet potato slices inoculated with *Salmonella*, exposed to five pre-drying treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dried for 6 h at 60°C (140°F).

	Control[2]		Steam Blanch[3]		Water Blanch[4]		0.105% Citric Acid[5]		0.21% Citric Acid[6]	
Processing steps	TSAP	XLD	TSAP	XLD	TSAP	XLD	TSAP	XLD	TSAP	XLD
Following inoculation[7]	6.58^{Aax} (0.22)	6.34^{Aax} (0.29)	6.58^{Aax} (0.22)	6.34^{Aax} (0.29)	6.58^{Aax} (0.22)	6.34^{Aax} (0.29)	6.58^{Aax} (0.22)	6.34^{Aax} (0.29)	6.58^{Aax} (0.22)	6.34^{Aax} (0.29)
Following pre-treatment (0 h)	6.58^{Aax} (0.22)	6.34^{Aax} (0.29)	2.01^{Bbx} (0.30)	1.56^{Bbx} (0.37)	1.23^{Bcx} (0.62)	<0.80	0.89^{Bcx} (0.55)	<0.80	<0.80	<0.80
Dehydration (1.5 h)	5.05^{ABax} (0.49)	4.58^{Bax} (0.35)	1.67^{Bbx} (0.74)	0.84^{Bby} (0.01)	1.24^{Bbx} (0.57)	0.82^{Bbx} (0.10)	1.52^{Bbx} (0.71)	0.91^{Bbx} (0.20)	1.36^{Bbx} (0.49)	0.80^{Bbx} (0.13)
Dehydration (3 h)	4.93^{Bax} (0.23)	4.16^{BCay} (0.21)	1.60^{Bbx} (0.94)	0.98^{Bbx} (0.13)	1.33^{Bbx} (0.16)	0.93^{Bbx} (0.02)	1.46^{Bbx} (0.27)	1.02^{Bbx} (0.13)	1.44^{Bbx} (0.69)	0.90^{Bbx} (0.04)
Dehydration (4.5 h)	4.59^{Bax} (0.27)	3.41^{Day} (0.27)	1.22^{Bbx} (0.22)	0.91^{Bbx} (0.02)	1.24^{Bbx} (0.29)	0.94^{Bbx} (0.0.02)	1.23^{Bbx} (0.24)	0.91^{Bbx} (0.06)	1.57^{Bbx} (0.68)	0.91^{Bbx} (0.01)
Dehydration (6 h)	4.73^{Bax} (0.17)	3.67^{CDay} (0.18)	1.22^{Bbx} (0.21)	0.90^{Bbx} (0.06)	1.19^{Bbx} (0.22)	1.09^{Bbx} (0.26)	1.19^{Bbx} (0.15)	1.05^{Bbx} (0.27)	1.03^{Bbx} (0.11)	0.93^{Bbx} (0.04)

[1] Means represent two samples in each of three replications (standard deviation of the replicates) of log colony forming units (CFU/g): lowest detection limit by plating, 0.80 log CFU/g (LSD: 0.74 log CFU/g).
[2] Control, inoculated w/ no pre-treatment, or inoculated and steam blanched[3] (88°C, 10 min), water blanched[4] (88°C, 4 min), blanched in 0.105% citric acid[5] (88°C, 4 min), or blanched in 0.21% citric acid[6] (88°C, 4 min). [7] Following inoculation (25°C, 30 min attachment time).
A-E means with different superscripts within a column are significantly different (P<0.05).
a-d means with different superscripts within a medium in the same row are significantly different (P<0.05).
x-y means with different superscripts within media of each treatment in a row are significantly different (P<0.05).

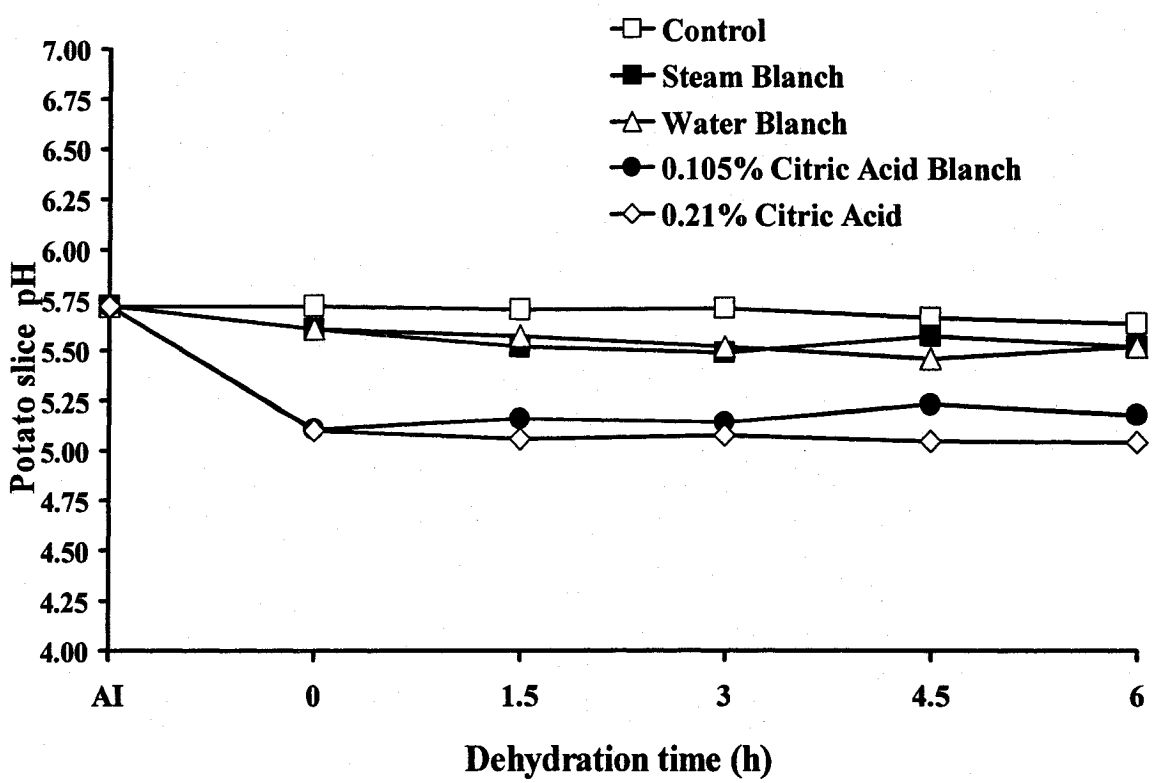

Figure 5.2. Mean pH of Russet potato slices during drying for up to 6 h following inoculation and various treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dried for 6 h at 60°C (140° F).

And from 0.12-0.17 at 6 h of dehydration (Table A5.3). Water activity values fluctuated from 0.12 to 0.47 throughout 30 d of storage. Potato slices were stored in plastic bags (aerobically) at ambient temperature (25 ± 3°C and 30 ± 6% relative humidity) which may have allowed some samples to gain moisture during storage. Nevertheless, all samples had a water activity below 0.60 throughout storage and, therefore, would be unlikely to sustain bacterial growth (Chirife and del Pilar Buera, 1996; Jay, 2000).

Bacterial populations immediately after blanching. *Salmonella* populations inoculated onto potato slices were significantly ($P<0.05$) reduced immediately following blanching compared to the control (Table 5.1). Specifically, initial populations (6.34-6.58 log CFU/g) were reduced by 4.57-4.78 and >5.35 log CFU/g immediately following steam and water blanching, respectively. *Salmonella* populations were below the detection limit (0.80 log CFU/g) immediately following acid blanching, except for samples blanched in 0.105% citric acid and recovered on TSAP (Table 5.1). The heat of blanching combined with the acidity of the blanch water most likely induced cellular stress, membrane damage, protein denaturation and/or DNA damage to injure, destroy and/or remove (washing effect) *Salmonella* cells from the potato slices (Kirby and Davies, 1990).

Bacterial populations during dehydration. Dehydration of inoculated, untreated (control) potato slices at 60°C for 6 h resulted in *Salmonella* reductions of 1.9 to 2.7 log CFU/g (Table 5.1). Bacterial population reductions on samples treated with steam blanching, water blanching, or blanching in 0.105% or 0.21% citric acid (5.3-5.6 log CFU/g) were significantly ($P<0.05$) greater compared to controls after 6 h dehydration (Table 5.1).

DiPersio et al. (2005a) evaluated the influence of recommended methods for

home-drying carrot slices including steam blanching (3 min), water blanching (3 min), or immersion in a 3.23% salt solution (5 min) before drying, or oven heating (80°C, 15 min) after drying on inactivation of *Salmonella* (7.8 log CFU/g) during dehydration of carrot slices. After 6 h of dehydration (60°C), all samples had populations ≥2.3 log CFU/g and, therefore, may present a food safety risk when contaminated.

In the current study, inoculated potato slices treated with extended steam blanching (10 min), water blanching (4 min) or acid blanching (4 min) had *Salmonella* populations of ≤1.22 log CFU/g after 6 h dehydration. Results suggest that extended steam blanching and water blanching with or without the addition of citric acid to the blanching water may have enhanced destruction of *Salmonella* on potato slices compared to some recommended methods such as steam blanching for 3 min and post-drying oven heating.

Yoon et al. (2004) evaluated the influence of steam blanching (88°C, 3 min), immersion in 0.21% citric acid (25 ± 3°C, 10 min), and drying (60°C, 14 h) on inactivation of *Salmonella* inoculated (7.1-7.4 log CFU/g) Roma tomato halves. Results indicated that steam blanching (3 min) had little affect on bacterial populations, but the combination of steam blanching and immersion in 0.21% citric acid enhanced inactivation of *Salmonella* during dehydration of tomato halves. In contrast, treatments used in the current study induced similar bacterial reductions throughout drying, regardless of whether samples were steam blanched, water blanched, or blanched in a citric acid solution. It appears that the extended time of steam blanching (10 min) and water or acid blanching (4 min) induced significant ($P<0.05$) bacterial reductions even before the application of dehydration.

Bacterial populations during storage. Bacterial populations on all samples continued to decrease throughout aerobic storage at ambient temperature (25 ± 3°C) (Table 5.2). After 30 d of storage, *Salmonella* populations ranged from 3.14 to 3.92 log CFU/g on potato slices left untreated and dehydrated for 6 h at 60°C. Extremely low numbers of salmonellae adapted to the dry state have been shown to cause illness (Lehmacher et al., 1995). Therefore, leaving potato slices untreated before drying may not effectively destroy pathogens that could be present in home-dried foods. *Salmonella* populations were undetectable by direct plating on all blanched samples (regardless of blanching method) at 30 d of storage. Steam blanching (10 min), water blanching (4 min) or blanching in 0.105% or 0.21% citric acid (4 min) enhanced inactivation of *Salmonella* during home-type dehydration of potato slices and, therefore, may enhance the safety of the final product if contaminated.

An increasing association between minimally processed produce and foodborne illnesses has prompted concern about the microbial contamination of these products (Beuchat, 2002; Natvig et al., 2002; Tauxe et al., 1997). Outbreak investigations indicate that only a very few *Salmonella* cells may be required to cause disease when consumed in low-water activity foods (CDC, 1995a, b, c; Greenwood and Hooper, 1983; Mackey and Derrick, 1982; Mattick et al., 2001). United States Cooperative Extension Services recommend blanching or immersion in a sodium chloride solution before drying, or oven heating after drying, to enhance the quality of home-dried vegetables. However, some commonly recommended treatments may not sufficiently destroy potential *Salmonella* contamination during home-type dehydration and storage of vegetable slices. The blanching treatments used in the present study significantly ($P<0.05$) reduced *Salmonella*

Table 5.2. Mean (log CFU/g[1]) bacterial (TSAP: tryptic soy agar with 0.1% pyruvate; XLD agar) populations (SD) on Russet potato slices inoculated with *Salmonella*, exposed to five pre-drying treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min), dried for 6 h at 60°C (140°F) and stored for up to 30 d at 25 ± 3°C.

	Control[2]		Steam Blanch[3]		Water Blanch[4]		0.105% Citric Acid[5]		0.21% Citric Acid[6]	
Storage Time	TSAP	XLD	TSAP	XLD	TSAP	XLD	TSAP	XLD	TSAP	XLD
0 d	4.73^{Aax} (0.17)	3.67^{Aay} (0.18)	1.22^{Abx} (0.21)	0.90^{Abx} (0.06)	1.19^{Abx} (0.22)	1.09^{Abx} (0.26)	1.19^{Abx} (0.15)	1.05^{Abx} (0.27)	1.03^{Abx} (0.11)	0.93^{Abx} (0.04)
5 d	4.19^{ABax} (0.15)	3.45^{ABay} (0.05)	1.29^{Abx} (0.49)	1.09^{Abx} (0.27)	1.24^{Abx} (0.16)	0.93^{Abx} (0.02)	1.46^{Abx} (0.33)	0.90^{Aby} (0.09)	1.62^{Abx} (0.46)	0.91^{Aby} (0.06)
15 d	3.62^{Bax} (0.83)	3.07^{Bay} (0.84)	1.30^{Abx} (0.13)	<1.10*	<1.10*	<1.10*	<1.10*	<1.10*	1.11^{Abx} (0.33)	<1.10*
30 d	3.92^{Bax} (0.17)	3.14^{Bay} (0.06)	<1.10*	<1.10*	<1.10*	<1.10*	<1.10*	<1.10*	<1.10*	<1.10*

[1] Means represent two samples in each of three replications (standard deviation of the replicates) of log colony forming units (CFU/g): lowest detection limit by plating, 1.1 log CFU/g (LSD: 0.47 log CFU/g).
[2] Control, inoculated w/ no pre-treatment, or inoculated and steam blanched[3] (88°C, 10 min), water blanched[4] (88°C, 4 min), blanched in 0.105% citric acid[5] (88°C, 4 min), or blanched in .210% citric acid[6] (88°C, 4 min).
A-E means with different superscripts within a column are significantly different (P<0.05).
a-d means with different superscripts within a medium in the same row are significantly different (P<0.05).
x-y means with different superscripts within media of each treatment in a row are significantly different (P<0.05).
* Detectable by enrichment only.

populations immediately following treatment, and throughout dehydration and storage of inoculated potato slices. Results suggest steam blanching (10 min), water blanching (4min) or blanching in a citric acid solution (4 min) may be an important first step in enhancing the safety of home-dried potato slices. Further research is needed to evaluate the sensory qualities of potato slices blanched in organic acid solutions before dehydration. Studies are also needed to understand *Salmonella* survival and growth in dried vegetables, and to develop recommendations for the home-type dehydration of vegetables.

CHAPTER VI

SENSORY EVALUATION OF DRIED FRUIT PREPARED USING TREATMENTS SHOWN TO ENHANCE DESTRUCTION OF *ESCHERICHIA COLI* O157:H7, *SALMONELLA* AND *LISTERIA MONOCYTOGENES*

ABSTRACT

Foodborne illness associated with dried foods has prompted research in the area of home food preservation. In this study, consumers evaluated the sensory characteristics (appearance, flavor, texture) of dehydrated fruits prepared using treatments shown to enhance pathogen destruction. Peach, pear, cantaloupe, apple, tomato and banana samples were left untreated or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid before dehydration (60°C). Untrained consumers (n = 280) participated in four sensory panels conducted over an eight month period. Consumers were primarily female students (21 to 34 years of age). Acid treatments maintained or improved the appearance and overall acceptability of dehydrated fruit pieces. Citric acid was more effective than ascorbic acid at preserving the color of dried peach, banana and tomato samples. Results suggest differences among fruits necessitate careful evaluation of treatments to maximize the quality of dried fruits. Guidelines for the safe and palatable preparation of dehydrated fruits are available through Cooperative Extension Services.

Introduction

Dehydration is the oldest and most common form of food preservation (Salunkhe and Kadam, 1995). Decreasing the moisture content of fresh produce provides a greater variety of fruits and vegetables throughout the year, and reduces the need for long-term, low-temperature storage (VanGarde and Woodburn, 1994). For the North American home food preserver, drying is a way to prepare specialty foods for snacks, gifts, backpacking and camping. The increased incidence of foodborne illness associated with low moisture foods such as home prepared meat jerky, chocolate and potato chips (CDC, 1995a, b, c; Eidson et al., 2000; Greenwood and Hooper, 1983; Kapperud et al., 1990; Keene et al., 19967; Lehmacher et al., 1995) has prompted the need for more research in the area of home food preservation.

For decades, home food preservers have used organic acid solutions to inhibit browning during dehydration and storage of fruits (Nijhuis et al., 1998; Tressler and DuBois, 1944). The effect of these treatments on product quality during dehydration and storage was the primary consideration at the time treatments were developed (Penfield and Campbell, 1990; Tressler and Dubois, 1944). Today, the challenge is to establish dehydration techniques that provide an added measure of safety without adversely affecting the sensory qualities of home-dried fruits.

Cooperative Extension Services across the United States have traditionally provided recommendations for drying fruits at home. In the spring of 2001, A survey was conducted of home fruit drying recommendations made by Cooperative Extension Services. Information was gathered from 27 states (DiPersio et al., 2003). Many of the publications recommended immersing fruit slices in ascorbic acid or citric acid solutions

to help preserve the color and quality of fruits throughout dehydration and storage. However, recommendations given varied widely and appeared to be based on anecdotal experience rather than scientific documentation. Studies evaluating the various recommended drying methods showed that treatments developed to maintain or improve the quality of home-dried foods may not improve their safety when contaminated (Burnham et al., 2001; DiPersio et al., 2005).

Burnham et al. (2001) evaluated the influence of commonly recommended treatments on *Escherichia coli* O157:H7 inoculated onto apple slices before home-type dehydration. Inoculated (8.7-9.4 log CFU/g) apple slices were immersed for 15 min (25 ± 3°C) in a 3.4% ascorbic acid solution or steam blanched (88.3°C, 3 min) prior to dehydration at 57.2°C or 62.8°C for 6 h. Untreated samples had a 2.9 log CFU/g reduction of *E. coli* O157:H7 following 6 h of dehydration. Steam blanching had little effect on the destruction of bacteria, while the ascorbic acid solution induced a 5-log reduction during drying at both temperatures.

Derrickson-Tharrington et al. (2005) found similar results for *E. coli* O157:H7 inoculated Gala apple slices immersed in 50% commercial lemon juice or a 1.7% citric acid solution prior to home-style dehydration. After 6 h of drying, *E. coli* O157:H7 populations were reduced by 6.7 to 7.3 log CFU/g on acid treated slices compared to only a 2.2 to 3.1 log CFU/g reduction on untreated samples. In a related study, immersion in 3.4% ascorbic acid or 1.7% citric acid solution before drying (60°C, 6 h) enhanced inactivation of *Salmonella* during home-type dehydration and storage of apple slices. DiPersio et al. (2004a) found that immersion in 3.4% ascorbic acid or 0.21% citric acid solutions, prior to dehydration (60°C, 6 h) of peach slices, enhanced destruction of

Listeria monocytogenes.

Yoon et al. (2004) assessed the influence of steam blanching (88°C, 3 min), immersion in 0.21% citric acid (25 ± 3°C, 10 min), and dehydration (60°C, 14 h) on the destruction of *Salmonella* inoculated (7.1-7.4 log CFU/g) onto Roma tomato halves. Steam blanching (3 min) was found to have little effect on bacterial populations, but the combination of steam blanching and immersion in 0.21% citric acid minimized survival of *Salmonella* during home-type dehydration and storage of tomato halves. Although blanching tomato halves in an acidic solution before drying is not traditionally used by home food preservers, the combination of heat and acid provides an added margin of safety. The sensory qualities of the finished product were not evaluated. As the above studies show, preserving foods with a combination of organic acids, temperature and water activity may maximize the destruction of pathogens when present, and improve the safety of home-dried foods. However, the influence of antimicrobial treatments on the sensory qualities of dried fruits was not studied.

Oxidative reactions in foods involve the removal of electrons from atoms or molecules, the creation of free radicals, and the development of undesirable flavors, discoloration of pigments and changes in texture (Dzeizak, 1986). Oxidation is catalyzed by several factors including oxygen, heat and alkaline conditions. Ascorbic acid (Vitamin C) acts as an antioxidant in foods by binding oxygen and becoming oxidized to dehydroascorbic acid, a stable molecule which does not initiate further oxidative reactions (Dzeizak, 1986). As an antioxidant, ascorbic acid works synergistically with other antioxidants by promoting their antioxidative action. For example, ascorbic acid regenerates phenolic antioxidants by contributing hydrogen atoms to phenoxyl radicals

produced during lipid oxidation (Dzeizak et al., 1986).

Ascorbic acid is generally recognized as safe (GRAS) for use as a chemical preservative (21 CFR 182.3013) and helps maintain the color of dried fruits by inhibiting nonenzymatic and enzymatic browning. Most of the browning that occurs in dehydrated foods is via the Maillard reaction (nonenzymatic browning) which may cause undesirable changes in appearance and flavor (Davidek et al., 1990). Nonenzymatic browning involves oxidation reactions between carbonyl groups of a reducing sugar and amine groups of a protein (Davidek et al., 1990; VanGarde and Woodburn, 1994) causing the formation of yellow, brown or black pigments called melanoidins (Davidek et al., 1990). The Maillard reaction functions in a specific pH range and, therefore, immersing light colored fruits in an ascorbic acid solution prior to dehydration will reduce pH and inhibit nonenzymatic browning (VanGarde and Woodburn, 1994).

Cutting fruits promotes enzymatic browning by permiting phenolic compounds to mix with endogenous polyphenol oxidase (PPO) and facilitating diffusion of atmospheric oxygen into the tissue. Hydroxylation of *o*-diphenols by PPO converts them to *o*-quinones, which are polymerized into brown pigments. Ascorbic acid minimizes PPO browning by reducing *o*-quinones back to phenolic compounds before they form brown pigments (Gil et al., 1998). In a study to evaluate the effect of ascorbic acid on browning of Fuji apple slices, acid treated samples were found to be lighter in color than untreated apple slices (Gil et al., 1998).

Ascorbic acid functions as an antibrowning agent in dried foods; however, its degradation can actually potentiate browning during the dehydration of some fruits (Negi and Roy, 2001). Ascorbic acid is easily oxidized to dehydroascorbic acid during heating

and if oxidation continues, it can not be reversed (Keshino and Ketitu, 1979; Negi and Roy, 2001). Dehydroascorbic acid is then available to react with proteins, propagate their degradation (Strecker degradation), and promote the formation of brown pigments (Devidek et al., 1990). Furthermore, flavor notes produced via Strecker degradation can cause undesirable flavor changes in the finished product (Devidek et al., 1990).

Chelating agents are not antioxidants but help stabilize foods by binding pro-oxidative metal ions, potentiating antioxidants and/or inactivating enzymes that cause color and flavor deterioration (Dziezak, 1986). Citric acid is a chelating agent used in the preservation of dried fruits, vegetables and meats, and is regarded as GRAS by the FDA (21 CFR 182.3013). Moline et al. (1999) found that citric acid was more effective than ascorbic acid as an antibrowning agent in fresh cut banana slices stored at 5°C for up to 7 days. The fact that ascorbic acid is an effective antibrowning agent in other fruits such as apples indicates that bananas and apples contain different types and/or concentrations of enzymes and substrates. Differences in pH may also account for dissimilar browning rates among fruits (Moline et al., 1999). Each fruit contains a unique complement of sugars, acids, enzymes and substrates that differ in reactivity and, therefore, it is necessary to identify the appropriate treatment to maximize the quality of each home-dried produce (Moline et al., 1995).

The sensory properties of a food directly influence product acceptability and consumer behavior, especially choice (IFT, 1981). The Sensory Division of the Institute of Food Technologists (IFT) defines the sensory evaluation as " a scientific discipline used to evoke, measure, analyze, and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch, and

hearing" (IFT, 1981). Descriptive testing is used to compare samples with respect to a specific characteristic. Panelists are asked to rate products on a numbered scale representing a range of low to high intensity of a characteristic. The most commonly used evaluation technique for measuring food acceptability and/or preference is the hedonic scale. Hedonic scales have five to nine points and include phrases such as "dislike extremely" and "like extremely" (Penfield and Campbell, 1990). Large panels (50-100) are used in this type of sensory evaluation and are often called consumer panels because untrained judges are used.

Burnham et al. (2001), Derrickson-Tharrington et al. (2005), and DiPersio et al. (2003, 2004a) developed treatments shown to reduce the risk of pathogen survival during home-type dehydration and storage of fruits. However, studies are needed to evaluate the acceptability of the finished product. The objective of the current study was to evaluate consumer responses to uninoculated dehydrated apple slices, banana slices, cantaloupe slices, peach slices, peach quarters, pear slices and tomato halves prepared using treatments found to enhance destruction of *E. coli* O157:H7, *Salmonella* and *L. monocytogenes* during home-type dehydration.

Materials and Methods

Sample Preparation. Samples were prepared in kitchens available in the Department of Food Science and Human Nutrition (Colorado State University, Fort Collins, CO). Fresh fruits were obtained from a local supermarket in the spring of 2004. Apples, bananas, cantaloupes, peaches and pears were washed, peeled and cut into slices (approximately 0.5 cm thick) using a hand-operated slicer. Simultaneously, peaches were cut in half, their stones removed manually, and cut into quarters (approximately 3-5 cm thick). Tomatoes were cut into halves approximately 3-5 cm thick. Treatments used were

derived from those found to enhance destruction of pathogens in dehydrated fruits (Burnham et al, 2001; Derrickson-Tharrington et al., 2005; DiPersio et al., 2003; DiPersio et al., 2004a). Samples were left untreated (control) or immersed (25 ± 3°C, 10 min) in 3.4% food grade ascorbic acid solution (pH 2.36 ± 0.20) (Fisher Scientific, Fair Lawn, NJ) or 1.7% food grade citric acid solution (pH 2.20 ± 0.25) (Fisher Scientific, Fair Lawn, NJ) and dried at 60°C (140°F) in home-type dehydrators (American Harvest Gardenmaster, model FD-1000, Nesco, Chaska, MN).

Drying temperature and times used were derived from those recommended in Cooperative Extension Service literature for dehydrating fruit slices (60°C, 6 h), peach quarters (60°C, 22 h) and tomato halves (60°C, 14 h) (Brennand, 1994; DiPersio et al., 2004b; Kendall and Allen, 1994; Mixon, 1998; Reynolds et al., 1993). The temperature of the circulating air was monitored throughout drying using a calibrated thermometer.

After drying, dehydrators were turned off and left (30 min) to allow for fruit to cool before handling. Fruit pieces were aseptically transferred to 1-quart Ziploc freezer bags which were left open, allowing fruit to cool in the bag at 25°C for an additional 24 hours. A sample, consisting of three apple, banana, cantaloupe, peach or pear slices (approximately 10 g), two peach quarters (approximately 12 g) or one tomato half (approximately 12 g), was selected randomly from each treatment and sealed in a snack-sized sterile plastic bag (Nasco, Modesto, CA), and identified with a 3-digit code number. Samples were kept frozen (4°C) until the time of testing.

Measurement of pH and water activity. The pH of dehydrated fruit samples from each treatment was measured using a digital pH meter with a glass pH electrode (Denver Instruments, Arvada, CO). Samples of each fruit from each treatment were analyzed for

water activity with a water activity meter (model AwQUICK, Rotronic Instrument Corp., Huntington, NY).

Panelists. Walk-up participants composed of students, faculty, staff and visitors to Colorado State University were recruited for the consumer sensory panel. Potential participants were told that some samples were treated with ascorbic acid or citric acid, both of which were used in low concentrations and approved by the U.S. Food and Drug Administration.

Test Procedure. Four sensory evaluation sessions with 40 to 100 participants per session were conducted over an eight month period. In the first session consumers (n = 100) evaluated dehydrated peach slices and quarters. In the second session consumers (n = 40) evaluated dehydrated cantaloupe and pear slices. A total of 100 consumers evaluated dehydrated apple slices and tomato halves in the third session, and 40 consumers evaluated dehydrated banana slices in session four. The Human Research Committee, Office of Regulatory Compliance, approved the consent forms and surveys used for the sensory evaluation. Subjects were asked to complete the consent form before participating in the sensory evaluation of dehydrated fruits (Appendix A and Figure A6.1).

Participants were seated in individually partitioned booths in a climate controlled sensory evaluation room. Coded samples were presented on a tray with the corresponding surveys (Figure A6.1). Trays also contained two unsalted crackers and a cup of tepid, distilled water for cleansing the palate between tasting samples. Samples were assessed under normal illumination. Participants scored dried fruit appearance, flavor acceptability and overall acceptability using a nine-point hedonic scale (1 = "dislike extremely"; 5 =

"neither like nor dislike"; 9 = "like extremely"). Samples were also evaluated for flavor description (1 = "extremely tart"; 9 = "extremely sweet/bland"), color (1 = "extremely light"; 9 = "extremely dark") and texture (1= "extremely brittle/hard"; 9 = "extremely soft/chewy"). Panelists were allowed to retaste samples and change rating scores. Seven demographic and behavioral questions were included in the surveys (Figure A6.1).

Statistical Analysis. Sensory data were analyzed with the Statistical Analysis System (SAS Institute version 9.1, Cary, NC). Specifically, sensory data for each fruit were analyzed separately comparing the three samples with a randomized block design. Comparisons between the sample means were done using least significant differences (LSD). A 5% significance level was used for comparisons. Means and standard deviations for pH and water activity data were calculated.

Results and Discussion

Water activity and pH. After 22 hours of dehydration at 60°C, the water activity values of peach quarters ranged from 0.46 to 0.55 (Figure 6.1 and Table A6.1). Tomato halves dried for 14 h at 60°C had water activity values (0.45-0.46) that were slightly lower than peach quarters. Compared to peaches, tomatoes are soft and porous, a structure which allows for rapid water removal during dehydration. Structural differences between peaches and tomatoes may account for the differences in drying time and water activity of the finished product. Water activity values of dried peach quarters and tomato halves were generally higher than water activity values (0.23-0.49) of dehydrated (60°C, 6 h) fruit slices (Figure 6.1 and Table A6.1). Results are not surprising and most likely due to the thickness of peach quarters (3-5 cm) and tomato halves (3-5 cm) compared to fruit slices (0.5 cm). Nevertheless, all samples had water activity values below 0.60, a level

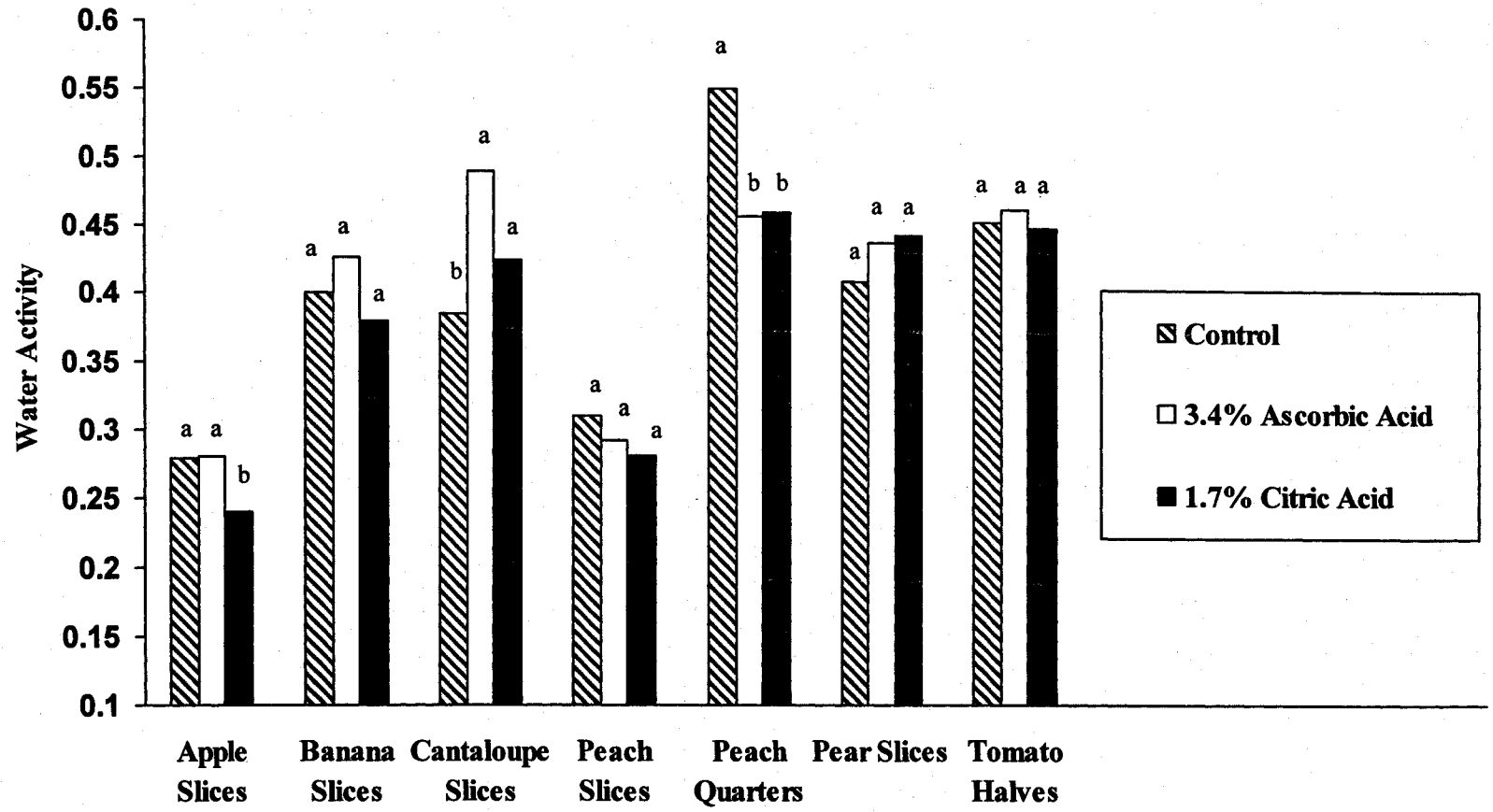

Figure 6.1. Mean (n= 6) water activity values for fruit pieces left untreated (control) or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid and dried at 60°C (140°F) for 6 h (apple slices, banana slices, cantaloupe slices, peach slices and pear slices), 14 h (tomato halves) or 22 h (peach quarters). Letters denote significant ($P<0.05$) differences among treatments within a fruit.

at which very few microorganisms are known to grow, and spoilage is unlikely to occur even over extended storage periods (Jay, 2000).

After dehydration, the pH values of untreated (control) apple slices (4.50 ± 0.28), banana slices (5.60 ± 0.40), cantaloupe slices (6.60 ± 0.38), peach pieces (4.08 ± 0.28), pear slices (5.60 ± 0.41), and tomato halves (4.50 ± 0.45) were near the normal range, respectively (FDA/CFSAN, 2000) (Figure 6.2 and Table A6.1). Acid treated fruit pieces had pH values that were significantly ($P<0.05$) lower than corresponding control values except for peach pieces. The pH of untreated peach pieces (4.08 ± 0.28) was relatively low and treatment with acidic solutions did not induce significant ($P>0.05$) reductions except for the reduction in pH of slices immersed in 1.7% citric acid (Figure 6.2 and Table A6.1). Apple slices, banana slices and pear slices immersed in citric acid prior to dehydration had pH values that were significantly ($P<0.05$) lower than untreated and ascorbic acid treated samples. Similarly, citric acid treated cantaloupe slices, peach slices and tomato halves had pH values that were significantly ($P<0.05$) lower than untreated samples, and generally lower than ascorbic acid treated samples (Figure 6.2 and Table A6.1). The 1.7% citric acid treatment tended to be more effective than the 3.4% ascorbic acid treatment in reducing the pH of fruit slices.

Sensory Panel Characteristics. A total of 280 untrained consumers participated in four sensory evaluation sessions (Session I, II, III and IV) over a period of eight months. Ten subjects were not included in the study due to incomplete paper work. Statistical analysis showed significant ($P<0.05$) differences among the four groups and, therefore, demographic data were analyzed separately for each session. Untrained panelists ($n = 97$) in Session I evaluated dried peach slices and quarters, and were primarily female

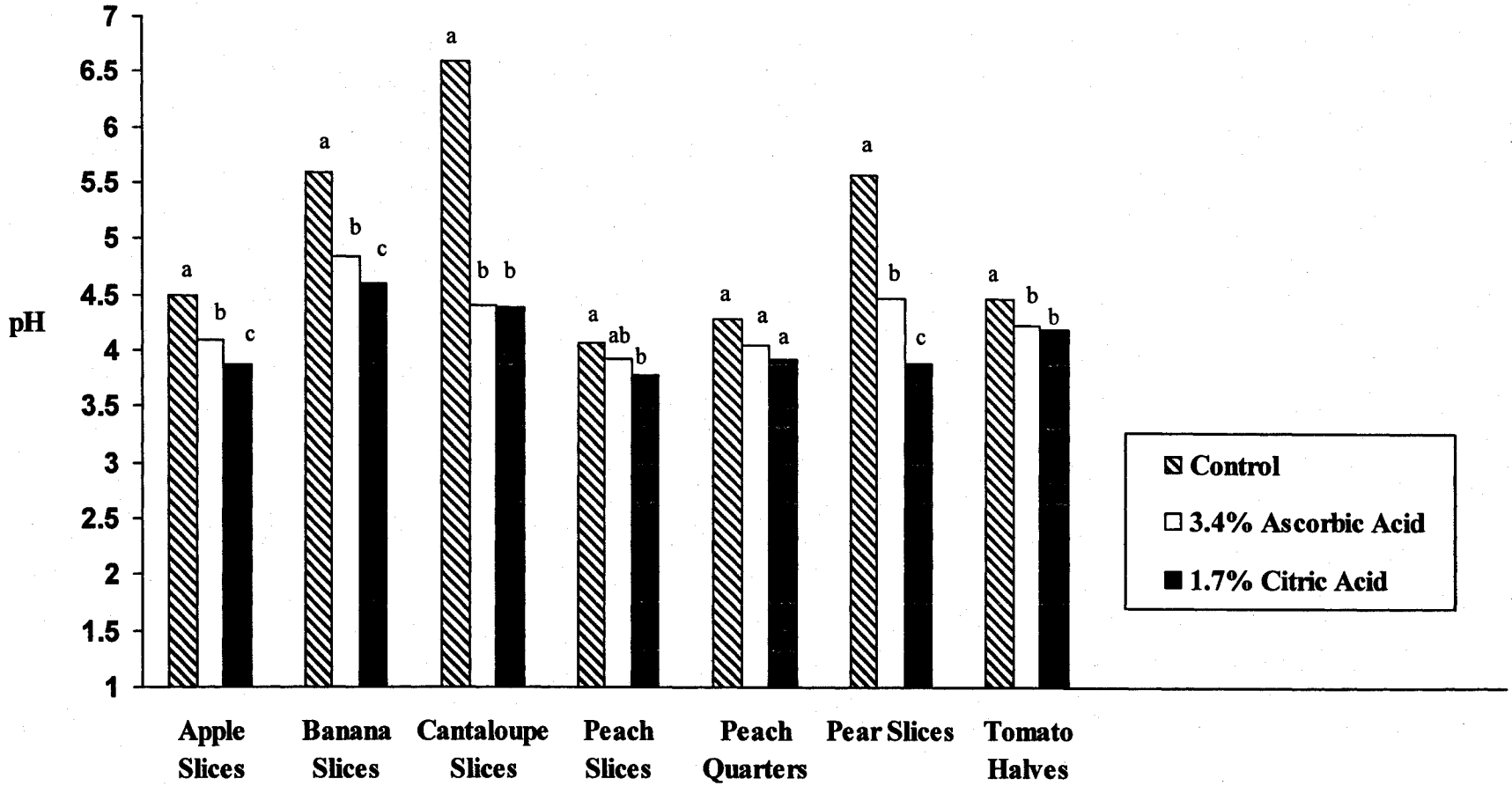

Figure 6.2. Mean (n= 6) pH values for fruit pieces left untreated (control) or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid and dried at 60°C (140°F) for 6 h (apple slices, banana slices, cantaloupe slices, peach slices and pear slices), 14 h (tomato halves) or 22 h (peach quarters). Letters denote significant ($P<0.05$) differences among treatments within a fruit.

(73.3%) students (82.5%) between the ages of 21 and 34 years (Table A6.2). Most (77.3%) had never dried fruits at home but liked eating dried fruits (82.1%). Sixty five percent of those who tasted dried peach samples ate dried fruit, and almost half purchased dried fruit between one and six times per year (Table A6.2).

Forty consumers evaluated dehydrated pear and cantaloupe slices in Session II (Table A6.3). Approximately 72% were female and most (70%) were students between 21 and 35 years of age (57.5%). Twenty percent of those who evaluated dried cantaloupe and pear slices had dried fruits at home, and 70% liked to eat dried fruits. Approximately 57% of participants in Session II ate dried fruit between one and six times per year, and 47.5% purchased dried fruit this often (Table A6.3).

Session III participants (n = 93) sampled dehydrated apple slices and tomato halves, and were primarily female (68.8%) students (77.4%) between 21 and 34 years of age (57%) (Table A6.4). Over 90% of panelists in Session III reported that they had never dried fruit at home and over half did not purchase or like to eat dried fruit (62.4% and 52.7%, respectively) (Table A6.4). In contrast, the majority (75%) of participants who tasted dried banana slices in Session IV liked to eat dried fruit and ate (65%) or purchased (52.5%) dried fruit between one and six times per year (Table A6.5). Results suggest that many participants in the current study liked, ate and purchased dried fruit but did not prepare it at home.

Sensory Evaluation. Regardless of treatment, overall acceptability scores for dried apple, banana, cantaloupe, peach and pear samples ranged from 5.0 to 6.7 on a nine point hedonic scale (1 = "dislike extremely", 5 = "neither like nor dislike", 9 = "like extremely") (Tables 6.1, 6.2, 6.3 and 6.4). Scores were above the median (4.5) and,

therefore, indicate moderate acceptability. Overall acceptability scores for dehydrated tomato halves ranged from 4.1 to 4.9, indicating suboptimum acceptability of all samples regardless of treatment (Table 6.3).

In Session I, peach quarters immersed in a 1.7% citric acid solution before dehydration were considered lighter ($P<0.05$) and more desirable ($P<0.05$) in appearance than all other samples (Table 6.1). In contrast, ascorbic acid treated peach quarters were considered darker ($P<0.05$) than untreated (control) and citric acid treated samples (Table 6.1). Perhaps the heat of drying induced the oxidation of ascorbic acid to dehydroascorbic acid, which catalyzed the degradation of proteins and the formation of brown pigments in dehydrated peach quarters (Davidek et al., 1990). Nevertheless, ascorbic acid treated peach quarters received similar scores for appearance, flavor and overall acceptability (Table 6.1) compared to controls. Panelists preferred ($P<0.05$) the appearance of acid treated peach slices over controls but all samples received similar scores for overall acceptability (Table 6.1).

Results of Session II showed that acid treated pear slices were regarded as more desirable ($P<0.05$) in appearance, somewhat lighter in color, and similar in flavor and overall acceptability compared to untreated samples (Table 6.2). Maga (1973) assessed the effect of color on potato chip preference and found that consumers preferred light colored chips over darker chips even before tasting samples. Perhaps the light color of acid treated pear slices influenced appearance ratings. Results indicate immersion in citric acid or ascorbic acid solutions prior to dehydration maintained or improved the appearance and overall acceptability of dried peach and pear samples. Mean scores for cantaloupe slice appearance (5.8-6.3), flavor acceptability (5.1-5.7) and overall

Table 6.1. Mean consumer (n = 97) ratings for sensory qualities of peach quarters and peach slices exposed to various treatments [control (untreated), or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid] and dried at 60°C (140°F) for 6 h (slices) or 22 h (quarters).

Peach Quarters	Appearance[1]	Flavor Acceptability[1]	Flavor Description[2]	Color[3]	Texture[4]	Overall Acceptability[1]
Control	4.6A	5.2A	5.3A	5.7B	5.2B	5.3A
3.4% Ascorbic Acid	4.2A	5.6A	4.9A	6.3C	4.3A	5.0A
1.7% Citric Acid	5.2B	5.7A	5.3A	5.1A	5.4B	5.5A
Peach Slices						
Control	5.9A	6.1B	5.3B	4.9A	4.8A	6.0A
3.4% Ascorbic Acid	6.7B	6.1B	4.4A	5.3A	4.7A	5.9A
1.7% Citric Acid	6.6B	5.4A	4.1A	5.0A	4.6A	5.5A

[1] Hedonic values are based on a nine-point scale (1 = "dislike extremely", 5 = 'neither dislike nor like", 9 = "like extremely").
[2] Flavor description values are based on a nine-point scale (1 = "extremely tart", 5 = 'neither tart nor sweet", 9 = "extremely sweet").
[3] Color values are based on a nine-point scale (1 = "extremely light", 5 = 'neither light nor dark", 9 = "extremely dark").
[4] Texture values are based on a nine-point scale (1 = "extremely brittle", 5 = 'neither brittle nor rubbery", 9 = "extremely rubbery").
A-C means with different letters within a sub-column are significantly different (P<0.05) LSD: 0.5 points.

Table 6.2. Mean consumer (n = 40) ratings for sensory qualities of pear slices and cantaloupe slices exposed to various treatments [control (untreated), or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid] and dried for 6 h at 60°C (140°F).

Pear Slices	Appearance[1]	Flavor Acceptability[1]	Flavor Description[2]	Color[3]	Texture[4]	Overall Acceptability[1]
Control	5.0A	6.2A	5.9A	4.8B	6.3B	6.0A
3.4% Ascorbic Acid	6.0B	6.6A	5.5A	4.3AB	5.9B	6.7A
1.7% Citric Acid	6.0B	6.4A	5.2A	3.7A	4.7A	6.0A
Cantaloupe Slices						
Control	6.1A	5.1A	5.9B	6.0A	5.1A	5.2A
3.4% Ascorbic Acid	5.8A	5.7A	5.4AB	5.6A	5.2AB	5.9A
1.7% Citric Acid	6.3A	5.2A	4.6A	5.9A	6.0B	5.3A

[1] Hedonic values are based on a nine-point scale (1 = "dislike extremely", 5 = 'neither dislike nor like", 9 = "like extremely").
[2] Flavor description values are based on a nine-point scale (1 = "extremely tart", 5 = 'neither tart nor sweet", 9 = "extremely sweet").
[3] Color values are based on a nine-point scale (1 = "extremely light", 5 = 'neither light nor dark", 9 = "extremely dark").
[4] Texture values are based on a nine-point scale (1 = "extremely brittle", 5 = 'neither brittle nor rubbery", 9 = "extremely rubbery").
A-B means with different letters within a sub-column are significantly different ($P<0.05$). LSD: 0.9 points.

Table 6.3. Mean consumer (n = 93) ratings for sensory qualities of apple slices and tomato halves exposed to various treatments [control (untreated), or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid] and dried for 6 h (apple slices) or 14 h (tomato halves) at 60°C (140°F).

Apple	Appearance[1]	Flavor Acceptability[1]	Flavor Description[2]	Color[3]	Texture[4]	Overall Acceptability[1]
Control	5.9A	6.6A	6.0C	5.8B	5.8A	6.7A
3.4% Ascorbic Acid	6.1A	6.5A	5.1B	3.8A	5.7A	6.7A
1.7% Citric Acid	5.7A	6.4A	4.3A	4.0A	5.4A	6.3A
Tomato						
Control	4.7A	4.2A	4.6A	5.7A	3.4A	4.1A
3.4% Ascorbic Acid	5.4B	4.8B	4.4A	6.2B	4.0B	4.5AB
1.7% Citric Acid	5.1AB	5.1B	4.7A	5.4A	4.4B	4.9B

[1] Hedonic values are based on a nine-point scale (1 = "dislike extremely", 5 = 'neither dislike nor like", 9 = "like extremely").
[2] Flavor description values are based on a nine-point scale (1 = "extremely tart", 5 = 'neither tart nor sweet", 9 = "extremely sweet").
[3] Color values are based on a nine-point scale (1 = "extremely light", 5 = 'neither light nor dark", 9 = "extremely dark").
[4] Texture values are based on a nine-point scale (1 = "extremely brittle", 5 = 'neither brittle nor rubbery", 9 = "extremely rubbery").
A-C means with different letters within a sub-column are significantly different ($P<0.05$). LSD: 0.5 points.

Table 6.4. Mean consumer (n = 40) ratings for sensory qualities of banana slices exposed to various treatments [control (untreated), or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid] and dried for 6 h at 60°C (140°F).

	Appearance[1]	Flavor Acceptability[1]	Flavor Description[2]	Color[3]	Texture[4]	Overall Acceptability[1]
Control	3.8A	5.3A	5.8A	5.2A	3.9A	5.1A
3.4% Ascorbic Acid	4.8B	6.5B	6.1A	6.7B	6.3B	6.2B
1.7% Citric Acid	5.8C	6.0AB	5.2A	4.6A	5.7B	6.0AB

[1] Hedonic values are based on a nine-point scale (1 = "dislike extremely", 5 = 'neither dislike nor like", 9 = "like extremely").
[2] Flavor description values are based on a nine-point scale (1 = "extremely tart", 5 = 'neither tart nor sweet", 9 = "extremely sweet").
[3] Color values are based on a nine-point scale (1 = "extremely light", 5 = 'neither light nor dark", 9 = "extremely dark").
[4] Texture values are based on a nine-point scale (1 = "extremely brittle", 5 = 'neither brittle nor rubbery", 9 = "extremely rubbery").
A-C means with different letters within a column are significantly different ($P<0.05$). LSD: 0.9 points.

acceptability (5.2-5.9) did not differ ($P>0.05$) among treatments, and indicated moderate acceptability of all samples (Table 6.2).

Citric acid treated pear slices and ascorbic acid treated peach quarters were considered more ($P<0.05$) brittle than untreated samples (Tables 6.1 and 6.2). Sapers and Miller (1995) reported that treatment with a heated (45-55°C) ascorbic acid/citric acid solution (1% and 2%, respectively) resulted in toughening of pre-peeled potatoes. Textural changes were thought to be related to acidification of enzymes resulting in free carboxyl groups of cell wall pectin and subsequent cross-linking by endogenous calcium (Sapers and Miller, 1995). Perhaps similar mechanisms were responsible for the brittle texture of acid treated pear and peach samples.

Panelists in Session III considered acid treated apple slices significantly ($P<0.05$) lighter and more tart than untreated samples (Table 6.3). Results were not surprising, since acid treated apple slices had significantly ($P<0.05$) lower pH values than untreated slices (Figure 6.2) which probably influenced flavor. Mean scores for apple slice appearance, flavor acceptability, texture and overall acceptability were not significantly ($P>0.05$) different among treatments. In contrast, acid treated tomato halves were considered somewhat more desirable in appearance and overall acceptability, and had a higher ($P<0.05$) flavor acceptability score compared to untreated samples (Table 6.3). Furthermore, panelists indicated that untreated tomato halves had a "bland flavor" compared to acid treated samples. Results suggest that the use of ascorbic acid or citric acid solutions in the preparation of home-dried apple slices and tomato halves maintained or improved the appearance, flavor acceptability and overall acceptability of the finished product (Table 6.3).

In Session IV, acid treated banana slices were considered more ($P<0.05$) desirable in appearance, and received somewhat higher scores for flavor acceptability and overall acceptability compared to untreated samples (Table 6.4). Comments provided by participants indicated that untreated banana slices were an "unappetizing brown color" compared to acid treated samples.

It is interesting to compare the effects of ascorbic acid and citric acid on each dried fruit. For example, acid treated banana and tomato samples were considered more ($P<0.05$) rubbery than untreated samples (Tables 6.3 and 6.4), but acid treatment seemed to have the opposite effect on peach quarters and pear slices (Tables 6.1 and 6.2). Perhaps compositional differences among bananas, tomatoes, peaches and pears resulted in textural differences observed among the dried products. Ascorbic acid treated peach quarters, banana slices.and tomato halves were significantly ($P<0.05$) darker, and ascorbic acid treated apple slices significantly ($P<0.05$) lighter than untreated samples. Although ascorbic acid is used to inhibit browning of dried fruits, its degradation may actually promote browning during the dehydration of certain fruits (Negi and Roy, 2001). Moline et al. (1999) found that ascorbic acid inhibited browning in fresh-cut apples and pears but not fresh-cut banana slices. Differences in composition, including types and amounts of sugars, acids, enzymes and substrates may influence the rate of ascorbic acid degradation and browning in different fruits. For example, bananas contain a unique balance of oxidizable enzymes and substrates including dihydroxyphenylalanine, while the primary oxidizable substrates in apples are phenolic acid conjugates (Moline et al., 1995; Monsalve-Gonzalez et al., 1995). Results of the current study suggest citric acid may be more appropriate than ascorbic acid for the preparation of home-dried peach

quarters, banana slices and tomato halves.

Under the conditions of the current study, immersing fruit pieces in 3.4% ascorbic acid or 1.7% citric acid solutions before home-type dehydration maintained or improved the appearance and overall acceptability of dehydrated peach pieces, pear slices, cantaloupe slices, apple slices, tomato halves and banana slices. Citric acid was more effective than ascorbic acid at inhibiting browning during the dehydration of peach, banana and tomato samples. Results suggest that compositional differences among fruits necessitate the careful evaluation of antibrowning treatments to maximize the color of each dehydrated fruit. Guidelines for the safe and palatable preparation of dried fruits are currently available to home food preservers through Colorado Cooperative Extension Services.

CHAPTER VII

FOOD DRYING WORKSHOPS PROMOTE SAFE HOME DRYING METHODS

ABSTRACT

Illnesses associated with dried foods have raised concerns about the safety of home drying methods. Studies at Colorado State University with apples, beef, carrots, parsley, peaches, potatoes and tomatoes showed traditional drying methods may allow survival of *Escherichia coli* O157:H7, *Salmonella* and *Listeria monocytogenes,* and that simple modifications enhanced pathogen inactivation during dehydration and storage. To encourage adoption of modified recommendations, a booklet, *Drying Foods*, and workshop were developed and pilot-tested with extension educators and volunteers (n=75). Social Cognitive Theory and the Health Belief Model guided development of the materials and workshop. Surveys assessed food drying knowledge, attitudes and behavior pre-, post and 6 weeks following the workshop. Sensory assessments of dried carrot and potato slices prepared using modified treatments enhanced experiential learning. Knowledge and attitude scores regarding safe food drying methods significantly ($P<0.05$) improved pre- to 6 week follow up evaluation. Participants also indicated improvements in food drying practices at the 6-week follow up. Acid blanched potato slices received higher ($P<0.05$) scores for appearance, flavor and overall acceptability compared to

untreated slices. Carrot samples received similar scores for flavor and acceptability regardless of treatment. Outcomes indicate improved subject knowledge, attitude and behavior, which may reinforce adoption of new food drying guidelines.

Introduction

Low moisture foods were once considered unlikely sources of foodborne illness; however, *Escherichia coli* infection and salmonellosis have been associated with consumption of chocolate, dehydrated milk, infant cereal, meat jerky, potato chips and a chip-type snack (CDC, 1995a, b, c; Eidson et al., 2000; Kapperud et al., 1990; Keene et al., 1997; Killalea et al., 1996; Lehmacher et al., 1995; ProMED-mail, 2003). For example, an outbreak of *E.coli* O157:H7 was linked to consumption of dried, fermented, ready-to-eat salami in Washington and California (CDC, 1995a). In 1995, an outbreak of *E. coli* O111:NM infection was associated with contaminated semi-dry fermented sausages resulting in hemolytic uremic syndrome in 23 children (CDC, 1995a). Also in 1995, an outbreak of *E. coli* O157:H7 infection was traced to deer jerky prepared in the home (Keene et al., 1997).

In New Mexico between 1966 and 1995, eight gastroenteritis outbreaks due to consumption of locally produced meat jerky contaminated with *Salmonella* and *Staphylococcus aureus* caused 250 illnesses (Eidson et al., 2000). In 1995, an outbreak of salmonellosis that caused at least 1000 illnesses was linked to contaminated potato chips. Levels of 0.04 to 0.45 cells per gram were found in the chips proving that even low numbers of salmonellae in low moisture foods may cause foodborne illness (Lehmacher et al., 1995).

From 1990 to 1999 the cumulative prevalence of *L. monocytogenes* in jerky

produced in federally inspected plants was 0.52% (Levine et al., 2001). *L. monocytogenes* is an environmental contaminant and listeriosis has a high fatality rate in high risk populations; therefore, the Food Safety Inspection Service (FSIS) established a zero tolerance (no detectable level permitted) for the pathogen in ready-to-eat foods. Beef jerky is included in the monitoring program (FSIS, 1999).

Cooperative Extension Services provide recommendations for drying foods at home, yet these recommendations may not always be based on scientific documentation. Studies on dried meats, fruits and vegetables have continued to show that traditional home drying methods may allow survival of pathogens, and that simple adjustments in preparation methods enhanced inactivation of bacteria during home-type dehydration and storage (Albright et al., 2002; Albright et al., 2003; Burnham et al., 2001; Calicioglu et al., 2002a, b; Calicioglu et al., 2003, Derrickson-Tharrington et al., 2005; DiPersio et al., 2003; DiPersio et al., 2004a, b; DiPersio et al., 2005a, b, c; Yoon et al., 2004). Albright et al. (2002) reported that beef strips inoculated with a 4-strain mixture of *E. coli* O157:H7 (5.7-7.5 log CFU/cm^2) and marinated using a traditional recipe, resulted in bacterial reductions of only 2.2 to 4.6 log CFU/cm^2 after 10 h of drying at 62.5 or 68.3°C. It was concluded that alternative treatments were needed to adequately destroy potential pathogen contamination during home-type dehydration of beef jerky. Albright et al. (2003) studied the fate of *E. coli* O157:H7 in beef jerky prepared using alternative treatments, dried in home-type dehydrators for up to 10 h at 62.5°C and stored at 21°C for up to 90 d. Among those evaluated, only the hot pickle cure method consistently resulted in a greater than 5-log reduction in bacteria during drying (5.7-5.8 log CFU/cm^2). A consumer panel (n=120) rated the jerky as moderately acceptable (3.7-3.9 on a 7-point

scale with 7 = extremely acceptable) (Albright et al., 2000). In a similar series of experiments, dipping meat slices in 5% acetic acid (vinegar) followed by traditional marinade (Harrison and Andress, 1999) improved the effectiveness of drying on enhancing reductions of *E. coli* O157:H7 (Calicioglu et al., 2002a), *Salmonella* (Calicioglu et al., 2003), and *L. monocytogenes* (Calicioglu et al., 2002b).

Cooperative Extension Services recommend immersing fruits in organic acid or sulfite solutions before home-type dehydration as an optional treatment to help preserve the inherent characteristics (appearance, texture) of the finished product (Archuleta, 2000; Brennand, 1994; DiPersio et al., 2004b; Harrison and Andress, 1999; Kendall and Allen, 1994; Mixon, 1998; Taylor, 2001). Studies at Colorado State University with apples, peaches and tomatoes showed traditional drying methods may allow pathogen survival but simple modifications enhanced inactivation of *E.* O157:H7, *Salmonella* and *L. monocytogenes* during fruit dehydration and storage. Specifically, immersion in 3.4% ascorbic acid, or 0.21% or 1.7% citric acid prior to dehydration (60°C or 62.8°C, 6 h) enhanced pathogen destruction during dehydration and storage (up to 30 d) of apple and peach slices (Burnham et al., 2001; Derrickson-Tharrington et al., 2005: , DiPersio et al., 2003: DiPersio et al., 2004a). Peeling and blanching combined with immersion in 3.4% ascorbic acid or 0.21% citric acid minimized the survival of *Salmonella* during home-type dehydration (60°C, 14 h) and storage (25°C, 28 d) of tomato halves (Yoon et al., 2004. Studies showed that fruit pieces treated with acidic solutions before dehydration were acceptable to consumers (Chapter VI).

Cooperative Extension Services recommend blanching or immersion in a salt solution before drying, or oven heating after drying, to inhibit browning and extend the

shelf life of home-dried vegetables (Brennand, 1994; Dinstel, 1999; Hughes and Willenberg, 1994; Kendall and Allen, 1998; Mixon, 2004; Okoli et al., 1988; Reynolds and Williams, 1993; Roberts and Cox, 1999; Swanson, 1995). DiPersio et al. (2005a) evaluated the influence of steam blanching (88°C, 3 min), water blanching (88°C, 3 min), immersion in 3.23% NaCl (25 ± 3°C, 5 min), and post-drying oven heating (80°C, 15 min) on *Salmonella* populations during dehydration (60°C, 6h) and storage of carrot slices. Inoculated (7.8 log CFU/g) carrot slices were left untreated or treated and dehydrated, or left untreated, dehydrated and heated (80°C, 15 min). All samples had populations >1.7 log CFU/g after 6 h of drying and 30 d of storage at 25°C. In a follow up study, DiPersio et al. (2005b) evaluated the influence of longer blanching times or blanching in acidic solutions on *Salmonella* populations during dehydration (60°C, 6 h) and storage of carrot slices. Inoculated (7.8 log CFU/g) slices were left untreated or steam blanched (88°C, 10 min), water blanched (88°C, 4 min), or blanched in a 0.105% or 0.21% citric acid solution (88°C, 4 min), dried for 6 h at 60°C (140°F), and stored for up to 30 d. After 6 h of dehydration, total reductions were 1.6-1.7 (untreated), 4.0-5.0 (steam blanched), 4.1-4.6 (water blanched) and 4.9-5.4 (acid blanched) log CFU/g. Populations were still detectable at 30 d on all samples except those blanched in 0.21% citric acid. Treatments induced similar *Salmonella* reductions in inoculated, dehydrated (60°C, 6 h) potato slices (DiPersio et al., 2005c). It was concluded that modified blanching treatments, particularly blanching in 0.21% citric acid before drying, may help destroy potential pathogen contamination during home-type dehydration and storage of carrot and potato slices.

Guidelines for the safe and palatable preparation of dried foods must be made

available to, and adopted by home food preservers to help reduce foodborne illness associated with home-dried foods. Specifically, home food preservers need knowledge of safe drying methods and motivation to act on that knowledge as preconditions to behavior change (Medeiros et al., 2004). The objectives of the current study were to develop theory-driven, research-based educational materials and train-the-trainer workshops designed to encourage adoption of acceptable (safety, taste, appearance) home drying guidelines for meat jerky, fruits and vegetables. Sensory assessments of dried carrot and potato slices left untreated or blanched in 0.105% or 0.21% citric acid before drying were included in the workshop to enhance experiential learning (Bandura, 1977; Bandura, 1989). Surveys were used to assess food drying knowledge, attitude and behavior immediately before (pre-), immediately following (post), and 6 weeks following (follow up) the intervention.

Materials and Methods

Participants. Participants (n=75) were recruited through Cooperative Extension Services and included Master Food Preservers, those enrolled in food preservation programs, Cooperative Extension agents and volunteers, and faculty, staff and students of Colorado State University. The Human Research Committee, Office of Regulatory Compliance, approved the consent forms and surveys used in the study (Appendix A and Figures A7.1 to A7.6).

Instrument Development. Elements of the Health Belief Model (Glanz et al., 1990; Janz et al., 1984) were used to develop pre-, post and follow up evaluation instruments to assess compliance with new behavior, and changes in knowledge and attitudes as a result of the workshop. Reliability was established using the test-retest method in small groups

of target audiences.

Questions addressing knowledge, attitude and behavior concerning the safe preparation of home-dried foods were reviewed by experts in the field of food safety, food microbiology and nutrition education for content validity, culled, then tested for reliability by 26 consumers who completed the surveys at 0 and 14 days without any food drying instruction in the interim (test, retest method). The McNemar's Test of symmetry for paired observations showed no significant ($P>0.05$) change from test to retest for items addressing subject knowledge, attitude and behavior, indicating item reliability. Cronbach's coefficient alpha for the ten knowledge and ten attitude questions was 0.75. A Cronbach's coefficient alpha of >0.70 indicates item homogeneity (Kline, 1993) and, therefore, all 20 questions were included in the evaluation instrument.

Education. The educational materials and workshop were designed to provide those trained both with an understanding of why changes are recommended and the skills to show others how to make the changes. Social Cognitive Theory and The Health Belief Model were used to develop theory-driven, research-based train-the-trainer workshops that promoted guidelines for safe home drying of meats, fruits and vegetables (Bandura, 1977, 1989; Glanz et al., 1990; Janz and Becker, 1984). Outcome expectancy is a person's estimate that a given behavior will lead to certain outcomes. This component of Social Learning Theory was used to develop educational materials designed to encourage adoption of revised home food drying recommendations. Specifically, materials included information about *E. coli* O157:H7 infection and salmonellosis related to consumption of home made meat jerky and paprika-powdered potato chips to increase participant awareness about potential risks. Methods found to enhance destruction of pathogens in

home-dried foods were explained and participants were encouraged to adopt these methods to reduce the risk of foodborne illness. Perceived threat (risk) and perceived benefits are important components of the Health Belief Model (Glanz et al., 1990). The ability of pathogens to survive the drying process and cause serious illness (perceived threat), and the ability of new preparation methods to minimize pathogen survival and the risk of illness (perceived benefit) were included in the workshop.

A 15 page bulletin, *Drying Foods* (Appendix B), containing guidelines for the safe preparation and storage of dried foods was developed as a teaching tool. A rating form was developed to evaluate the bulletin's understandability, usefulness, believability, graphics and overall liking (Figure A7.4). The two-hour workshop included background information on foodborne pathogens, general food safety information, and recommendations and demonstrations on the safe preparation, handling and storage of home-dried foods. Sensory evaluations of dehydrated carrot and potato slices left untreated (control), or blanched in a 0.105% or 0.21% citric acid solution (88°C, 4 min) were included as an experiential element of the workshop.

Sample Preparation for Sensory Evaluation. Samples were prepared in kitchens available in the Department of Food Science and Human Nutrition (Colorado State University, Fort Collins, CO). Fresh carrots and potatoes were obtained from a local supermarket in the spring of 2004, washed, peeled and sliced into circular discs (3 mm thickness) using a hand-operated slicer. Treatments and drying times used were derived from those found to enhance destruction of pathogens in dehydrated carrot and potato slices (DiPersio et al., 2005a, b, c). Slices were left untreated (control) or blanched (88°C, 4 min) in 0.105% or 0.21% citric acid (Fisher Scientific, Fair Lawn, NJ), and dehydrated

for 6 h at 60°C (140°F) in home-type dehydrators (American Harvest Gardenmaster, model FD-1000, Nesco, Chaska, MN).

After drying, dehydrators were turned off and left for 30 min to allow for samples to cool. Vegetable slices were removed from the dehydrators with rubber gloves and placed in 1-quart Ziploc freezer bags (Nasco, Modesto, CA). Bags were left open, allowing samples to cool in the bags at 25°C for an additional 24 h. One sample, consisting of 12 carrot slices (approximately 10g) or 2 potato slices (approximately 10g), was selected randomly from each treatment and placed in individual Ziploc snack-size bags (Nasco, Modesto, CA) each identified with a 3-digit code number. Samples were kept frozen (4°C) until the time of testing.

Sensory Evaluation. As part of the training workshop, each participant received a tray containing coded samples, two unsalted crackers, a cup of tepid, distilled water for cleansing the palate and corresponding surveys (Figure A7.1 and Figure A7.5). Dried carrot and potato sensory evaluation surveys were developed in accordance with Institute of Food Technologist (IFT) guidelines (IFT, 1981) and included six sensory characteristics (appearance, flavor description, flavor acceptability, color, texture, overall acceptability), along with corresponding description terms. Respondents rated dried vegetable slice appearance, flavor acceptability and overall acceptability using a nine-point hedonic scale (1 = "dislike extremely"; 5 = "neither like nor dislike"; 9 = "like extremely"). Samples were also evaluated for flavor description (1 = "extremely tart"; 9 = "extremely sweet/bland"), color (1 = "extremely light"; 9 = "extremely dark") and texture (1= "extremely brittle/hard"; 9 = "extremely soft/chewy"). Participants were allowed to retaste samples and change rating scores. Panelists were aware that some

samples were blanched in citric acid which may have influenced their responses. Demographic and behavioral questions were also included in the survey (Figure A7.5).

Physical Analysis. Carrot and potato slices from each treatment were analyzed for pH and water activity. The pH of samples was measured using a digital pH meter with a glass pH electrode (Denver Instruments, Arvada, CO). Samples were analyzed for water activity according to AOAC International official method 978.18 (AOAC, 1998) with a water activity meter (model AwQUICK, Rotronic Instrument Corp., Huntington, NY).

Statistical Analysis. Data were analyzed with the Statistical Analysis System (SAS Institute version 9.1, Cary, NC). Internal consistency of survey knowledge and attitude questions was measured using Cronbach's alpha. McNemar's Test of symmetry for paired, categorical data was used to assess differences in survey responses from test to retest. The McNemar's Test and T-Tests were used to test for differences between pre- and post, pre- and follow up, and post and follow up survey responses. Sensory data for each vegetable were analyzed separately comparing the three samples with a randomized block design. Comparisons between the sample means were done using least significant differences (LSD). A significance level of 0.05 was used for all statistical analyses. Means and standard deviations for pH and water activity data were calculated.

Results and Discussion

Demographics. Of the 75 consumers who participated in the workshop, 53 completed and returned the follow up survey. Participants (n = 53) were primarily female (88.7%), white (88.2%) and between the ages of 35 and 64 years (83%) (Table 7.1). With regard to affiliation, 45.3% of participants identified themselves as Master Food Preservers, 30.2% as Cooperative Extension Agents, 5.7% as 4H Leaders or volunteers and 18.9% as

Table 7.1. Demographic characteristics of participants in food drying workshop (n = 53).

Characteristic	n	%
Age		
<35 yr	4	7.6
35-44 yr	15	28.3
45-54 yr	15	28.3
55-64 yr	14	26.4
>64 yr	5	9.5
Gender		
Female	47	88.7
Male	6	11.3
Race (n = 51)		
White	45	88.2
Hispanic	3	5.9
Mixed Race/Other (Black, Asian)	3	5.9
Affiliation		
Master Food Preserver	24	45.3
Cooperative Extension Agent	16	30.2
4H Leader/Volunteer	3	5.7
Consumer/Other	10	18.9
Did you dry foods in the past year?		
No	24	45.3
Yes	29	54.7
If yes, what foods?		
Meats	10	18.9
Fruits/Fruit Leathers	22	41.5
Vegetables	14	26.4
Herbs	14	26.4
Did you dry foods in the past 5 years?		
No	18	34.0
Yes	35	66.0
If yes, what foods?		
Meats	19	35.8
Fruits/Fruit Leathers	27	50.9
Vegetables	21	39.6
Herbs	22	41.5

consumers. Approximately 55% of respondents had dried foods in the past year and of these, 34.5% had dried meats, 75.9% fruits/fruit leathers and 48.3% vegetables and/or herbs. In the past five years, 66% of participants reported that they had dried foods at home (Table 7.1).

Education Outcomes. Knowledge items were scored on a scale of agree/disagree, and a percent correct score was calculated for each item (Table 7.2). McNemar's Test showed that the initial (pre-workshop) overall mean score for knowledge items (73.8% correct) significantly ($P<0.05$) improved immediately following (91.6% correct), and six weeks following (90.0% correct) participation in the training workshop (Table 7.2). Knowledge is factual information that a learner uses to perform a task in a desired manner, and must precede behavior change (Medeiros et al., 2001; Medeiros et al., 2004).

Before attending the workshop, approximately 85% of subjects were aware that foodborne illness has been associated with meat jerky (Table 7.2). Knowledge scores for this item significantly ($P<0.05$) improved immediately following (100% correct) and six weeks following (98.1% correct) the education intervention (Table 7.2). Before the intervention, approximately 77% of participants agreed that treating fruits with an acidic dip may enhance destruction of bacteria during drying. However, pre-workshop survey scores showed that only 59.6% of subjects agreed water blanching may enhance bacterial destruction during vegetable drying. Immediately following the intervention, knowledge scores significantly ($P<0.05$) improved for the first item (98.1% correct), and somewhat improved for the second item (76.9% correct) compared to pre-workshop scores. Scores for the first item were somewhat higher, and for the second item significantly ($P<0.05$) higher 6 weeks following the intervention (Table 7.2). Results of the pre-workshop

Table 7.2. Mean knowledge scores[a] pre-, post (immediately following) and 6 weeks following participation in food drying workshop (n = 53).

Question	Percent Correct		
	Pre-	Post	Follow up
1. Foodborne illness outbreaks have been associated with beef jerky and venison jerky.[b]	84.6^{A}	100.0^{B}	98.1^{B}
2. Microorganisms are not able to grow or survive on dried fruits and vegetables.[c]	84.9^{A}	100.0^{B}	100.0^{B}
3. In the past 15 years, the number of produce-associated foodborne illness outbreaks per year has decreased.[c]	84.9^{A}	88.7^{A}	88.7^{A}
4. To maintain the best flavor and quality, store jerky in the refrigerator or freezer.[b]	83.0^{A}	92.5^{A}	96.2^{A}
5. Dipping fruits in a solution containing ascorbic acid (Vitamin C), citric acid, or lemon juice may help enhance the destruction of microorganisms during drying.[b]	77.4^{A}	98.1^{B}	88.7^{AB}
6. Steam blanching vegetables before drying effectively enhances destruction of microorganisms.[b]	24.5^{A}	73.6^{B}	62.3^{B}
7. Water blanching vegetables before drying effectively enhances destruction of microorganisms.[b]	59.6^{A}	76.9^{B}	84.6^{B}
8. Sun/solar drying is a safe way to dry meats.[c]	90.6^{A}	100.0^{B}	100.0^{B}
9. Sun/solar drying is a safe way to dry fruits and vegetables.[c]	56.6^{A}	100.0^{B}	98.1^{B}
10. Dried fruits and vegetables should never be conditioned before storage.[c]	92.0^{A}	86.0^{A}	80.0^{B}
Overall knowledge score	73.8^{A}	91.6^{B}	90.0^{B}

[a] Knowledge items were scored on a scale of agree/disagree and presented as percent correct (% Correct) for each item.
[b] Scored on a scale of agree = correct and disagree = incorrect.
[c] Scored on a scale of disagree = correct and agree = incorrect.
A-B values with different superscripts within a row are significantly different ($P<0.05$).

evaluation showed 43.4% of participants agreed that solar drying was a safe way to dehydrate produce. However, solar drying does not provide a steady source of heat and allows for the introduction of contaminants and, therefore, is not recommended (DiPersio et al., 2004b). Post workshop and follow up evaluations showed that 98.1 to 100% of participants agreed solar drying was not a safe way to prepare dried produce (Table 7.2).

Attitude items were scored on a scale of agree/disagree and presented as respondent's percent agreement (% agree) with the most safe food drying attitude (Table 7.3). McNemar's Test showed that overall mean scores for attitude items significantly ($P<0.05$) improved from 86.7% agree (pre-workshop evaluation) to approximately 98% agree immediately and 6 weeks following the workshop (Table 7.3). An attitude is learned through the environment and can be used to predict the likelihood that a person will be motivated to move to action (Fishbein, 1967; Glanz et al., 1990; Kline, 1993; Medeiros et al., 2001).

According to pre-survey scores, approximately 10-15% of participants were not worried that dried foods may be contaminated with microorganisms and make them sick (Table 7.3). However, in New Mexico between 1966 and 1995, 250 illnesses were traced to consumption of meat jerky contaminated with *Salmonella* and *Staphylococcus aureus* (Eidson et al., 2000). In 1995, an outbreak of *E. coli* O157:H7 infection was traced to home made deer jerky (Keene et al., 1997), and approximately 1000 cases of salmonellosis were linked to contaminated potato chips (Lehmacher et al., 1995). Immediately following, and 6 weeks following the education intervention >98% of participants were concerned about the safety of dried foods.

Table 7.3. Respondent's attitude[a] toward the safe preparation of home dried foods pre-, post (immediately following) and 6 weeks following participation in food drying workshop (n = 53).

Question	Percent Agree		
	Pre-	Post	Follow up
1. I think it's important to monitor oven temperature throughout food drying.[b]	94.3^{A}	98.1^{A}	100.0^{A}
2. I think it's important to monitor dehydrator temperature throughout food drying.[b]	90.4^{A}	96.2^{A}	98.1^{A}
3. I don't worry that jerky may be contaminated with microorganisms and make me sick.[c]	90.6^{A}	100^{B}	100^{B}
4. I don't worry that dried fruits and vegetables may be contaminated with microorganisms and make me sick.[c]	84.9^{A}	98.1^{B}	100^{B}
5. I am not concerned about case-hardening of meats during drying.[c]	75.5^{A}	100^{B}	100^{B}
6. I am not concerned about case-hardening of fruits and vegetables during drying.[c]	72.9^{A}	100^{B}	97.9^{B}
7. I don't think it's important to store dried meats (jerky) in airtight containers.[c]	100^{A}	100^{A}	98.1^{A}
8. I don't think it's important to store dried fruits and vegetables in airtight containers.[c]	98.1^{A}	100^{A}	100^{A}
9. I think it's better to dry foods in a food dehydrator than an oven.[b]	77.4^{A}	98.1^{B}	98.1^{B}
10. I think it's important to condition dried meats before packing them for storage.[b]	82.4^{A}	90.2^{A}	93.5^{A}
Overall attitude score	86.7^{A}	98.0^{B}	98.6^{B}

[a] Attitude items were scored on a scale of agree/disagree and presented as respondent's percent agreement (% Agree) with the most safe food drying attitude.
[b] Scored on a scale of agree = most safe attitude and disagree = least safe attitude.
[c] Reverse coded so agree = most safe attitude
A-B values with different superscripts within a row are significantly different ($P<0.05$).

As indicated by pre-survey results, only 72 to 76% of participants were concerned about case hardening during dehydration of meats and produce (Table 7.3). Case hardening occurs when heat is applied too rapidly during drying, the outer layer of the food dries too quickly and further moisture release from the center of the food is prevented (Nichols, 1978). Case hardening and moisture retention in dried foods leads to rapid spoilage and, if present, the potential survival of harmful bacteria (Bower and Daeschel, 1999). Immediately following, and 6 weeks following participation in the workshop 98% to 100% of participants reported that they were concerned about case hardening in dried foods (Table 7.3). Pre-workshop survey scores showed that approximately 77% of workshop participants agreed it was better to dry foods in a food dehydrator than the oven while post and follow up survey scores showed that 98.1% of participants agreed with the statement (Table 7.3).

A five point scale (1 = "I don't usually do this", 3 = "I sometimes do this", 5 = "I have always done this") was used to evaluate participants' food drying behaviors immediately before and six weeks following the workshop. Pre-workshop and follow up surveys included the items: "I use a thermometer to monitor oven temperature during drying" and "Before drying fruit slices/pieces, I dip (them) in a citric acid solution". Compared to pre-workshop survey responses, follow up survey responses indicate that participants were more likely ($P<0.05$) to monitor oven temperature with a thermometer after attending the workshop (4.1 ± 1.8 pre- vs. 4.8 ± 0.9 follow up). In comparison with the pre-workshop evaluation, results of the follow up evaluation indicated that respondents were somewhat more likely to immerse fruit slices/pieces in a citric acid solution before drying (2.6 ± 1.6 and 3.5 ± 1.4, respectively) (Table 7.4). Research

indicates that immersion in a citric acid solution before drying enhanced destruction of pathogens during home-type dehydration and storage of apple and peach slices (Derrickson-Tharrington et al., 2005; DiPersio et al., 2003; DiPersio et al., 2004a).

The pre-workshop survey included the question; "I would rate my food drying practices as", and the follow up survey included the questions; "before attending the workshop, I would rate my food drying practices as" and "as a direct result of attending the workshop, I would now rate my food drying practices as". A five point scale (1 = "Unsafe", 3 = "Somewhat safe", 5 = "Extremely safe") was used to evaluate participant's responses. The pre-workshop item ("I would rate my food drying practices as") had a mean score that was significantly ($P<0.05$) higher than the mean score for the follow up item "before attending the workshop, I would rate my food drying practices as" (4.4 ± 1.2 and 3.7 ± 1.1, respectively) (Table 7.5). Participant's rated their pre-workshop food drying practices as less safe 6 weeks after attending the workshop, and indicated that the safety of their food drying practices improved as a direct result of attending the workshop (3.7 ± 1.1 pre- vs. 4.8 ± 0.7 follow up) (Table 7.5).

Workshop participants rated the *Drying Foods* bulletin for understandability, usefulness, willingness to follow and overall likeability (Table A7.1). Mean scores ranged from 6.2 to 6.7 on a seven point scale (1 = "not very easy to understand", "not very useful", "not very willing to follow" or "dislike extremely" to 7 = "very easy to understand", "very useful", "very willing to follow" or "like extremely"). Mean scores for these items were well above the median (3.5) and, therefore, indicate that participants liked the *Drying Foods* bulletin, found it somewhat useful and easy to understand, and were willing to follow recommendations (Table A7.1). Feedback was used to guide the

Table 7.4. Food drying behavior patterns pre- and 6 weeks following participation in food drying workshop.

	Pre-workshop behavior patterns							Behavior patterns 6 weeks following the workshop						
	Mean[a]	SD	1(n)	2(n)	3(n)	4(n)	5(n)	Mean[a]	SD	1(n)	2(n)	3(n)	4(n)	5(n)
Before drying meat slices:														
I do nothing	1.9	1.6	10	0	2	1	2	1.4	1.3	8	0	0	0	1
I pre-cook meat slices to 160°F	2.7	1.7	8	2	3	1	4	2.7	1.6	4	0	4	1	2
I treat meat slices with pickling spices, then a hot pickling brine	2.8	1.7	7	2	2	3	4	2.9	1.6	2	0	3	4	2
I marinade the meat slices	3.7	1.4	2	1	4	4	7	3.7	1.3	2	0	2	4	4
I dip meat slices in vinegar, then marinade	2.3	1.8	11	0	2	2	3	2.8	1.5	1	3	2	3	2
Before drying fruit slices/pieces:														
I do nothing	1.7	1.3	19	0	1	3	1	1.4	1.0	23	1	1	1	1
I dip fruit pieces in a solution of half lemon juice/half water	2.6	1.5	7	0	6	7	4	2.9	1.5	9	0	11	2	6
I dip fruit pieces in a citric acid solution	2.6	1.6	9	2	7	4	6	3.5	1.4	4	0	8	8	8
I dip fruit pieces in an ascorbic acid/Vitamin C solution	3.4	1.4	6	1	9	8	7	3.5	1.4	5	2	7	7	8
I dip fruit pieces in a sulfite solution	1.3	0.7	23	1	3	0	1	1.3	0.9	24	0	2	0	1
Before drying vegetable slices/pieces:														
I do nothing	1.3	0.6	11	1	2	0	0	1.5	1.2	10	0	0	1	1
I steam blanch vegetable pieces	2.5	1.3	5	1	6	2	2	2.6	1.7	6	2	0	3	2
I water blanch vegetable pieces	3.1	1.7	4	0	3	2	6	3.6	1.7	4	0	1	3	5
I water blanch pieces in a citric acid solution	1.8	1.4	12	0	1	1	1	1.7	1.1	7	3	1	2	0

[a] Mean scores (SD) are based on a five-point scale (1 = "I don't usually do this", 3 = "I sometimes do this", 5 = "I have always done this"). Differences were not significant (P>0.05).

Table 7.5. Food drying behavior patterns pre- and 6 weeks following participation in food drying workshop.

	Pre-workshop behavior patterns							Behavior patterns 6 weeks following the workshop						
	Mean [a]	SD	1(n)	2(n)	3(n)	4(n)	5(n)	Mean [a]	SD	1(n)	2(n)	3(n)	4(n)	5(n)
I would rate my food drying practices as:	4.4B	1.2	1	1	9	17	13							
Before attending the workshop, I would rate my food drying practices as:								3.7A	1.1	0	4	23	15	4
As a **direct result** of attending the workshop, I would **now** rate my food drying practices as:								4.8B	0.7	0	0	2	12	33

[a] Mean scores (SD) are based on a five-point scale (1 = "Unsafe", 3 = "Somewhat Safe", 5 = "Extremely Safe").
A-B values with different letters are significantly different ($P<0.05$).

modification of content and format of the *Drying Foods* bulletin.

Sixty six percent of workshop participants (n = 53) had prepared dried meat, fruit and/or vegetables at home. However, the overall mean score for knowledge questions on the pre-workshop survey was 73.8%, indicating the need for an educational intervention. McNemar's Test showed that the overall mean score for knowledge items significantly ($P<0.05$) improved immediately following (91.6% correct), and six weeks following (90.0% correct) participation in the training workshop (Table 7.2). Similarly, overall mean scores for respondent's percent agreement with the most safe food drying attitude significantly ($P<0.05$) improved from 86.7% agree (pre-workshop) to approximately 98% agree immediately and 6 weeks following workshop participation (Table 7.3). Compared to the pre-workshop evaluation, results of the follow up evaluation suggest that participants were more likely ($P<0.05$) to practice some safe food drying behaviors such as monitoring oven temperature during drying. Furthermore, participants believed the safety of their food drying practices improved as a direct result of attending the training workshop (Table 7.5).

Effective food safety education programs increase participants' knowledge and awareness about food safety risks, and motivate them to change their behaviors (Medeiros et al., 2001). Movement toward a desired behavior can be used to assess the effectiveness of an educational intervention (Medeiros et al., 2001). Specifically, participants can be assessed in a paired pre/post format, change in self reported behavior can be tracked, and progress toward achieving ideal behavior can be reported as a successful outcome of the intervention (Medeiros et al., 2001). Results of the current study suggest that participants were more likely to practice some safe food drying

behaviors after attending the training workshop, thus achieving progress toward ideal food drying behavior and indicating effectiveness of the educational intervention.

Sensory Evaluation. Carrot slices blanched in 0.105% or 0.21% citric acid prior to dehydration had significantly ($P<0.05$) higher scores for appearance than did slices left untreated before drying (Table 7.6). Consumer comments indicated that untreated carrot slices had a shriveled/crumpled appearance compared to acid blanched samples. Pectins are a main structural component of the plant cell wall and are susceptible to enzymatic degradation (Levi et al., 1988). Enzyme induced changes in pectins affect the structural characteristics of plant tissue and may influence the overall appearance of dehydrated vegetables (Hulme, 1971; Levi et al., 1988; Negi and Roy, 2001). In the current study, blanching prior to dehydration helped maintain the appearance of dried carrots, perhaps due to the inactivation of enzymes and stabilization of pectins (Levi et al., 1988; Negi and Roy, 2001). Citric acid blanched carrot slices were considered significantly ($P<0.05$) more brittle/hard than controls. Textural effects may have been due to the acidification of pectin enzymes during treatment with heat and acid, resulting in increased free carboxyl groups of cell wall pectin and subsequent cross-linking by endogenous calcium as proposed by Sapers and Miller (1995) and Bartolome and Hoff (1972). Nevertheless, all carrot samples received similar scores for flavor acceptability, flavor description and overall acceptability regardless of pre-drying treatment (Table 7.6).

Mean scores for potato slices blanched in 0.105% or 0.21% citric acid before dehydration were significantly higher ($P<0.05$) for appearance, flavor acceptability and overall acceptability compared to untreated samples (Table 7.6). Furthermore, consumers considered acid blanched potato slices somewhat lighter in color than untreated samples.

Table7.6. Mean (n=75) ratings for sensory qualities of carrot slices and potato slices left untreated (control), blanched in 0.105% citric acid (88°C, 4 min) or blanched in 0.21% citric acid (88°C, 4 min), and dried for 6 h at 60°C (140°F).

Carrot Slices	Appearance[1]	Flavor Acceptability[1]	Flavor Description[2]	Color[3]	Texture[4]	Overall Acceptability[1]
Control	4.71 ^{A}	6.04 ^{A}	5.97 ^{A}	3.78 ^{A}	4.97 ^{A}	5.84 ^{A}
0.105% Citric Acid	6.49 ^{B}	5.78 ^{A}	5.78 ^{A}	6.45 ^{B}	3.82 ^{B}	5.73 ^{A}
0.21% Citric Acid	6.04 ^{B}	4.84 ^{A}	5.22 ^{A}	6.37 ^{B}	3.51 ^{B}	4.67 ^{A}
Potato Slices						
Control	2.82 ^{A}	3.02 ^{A}	4.06 ^{A}	4.51 ^{A}	3.51 ^{A}	2.92 ^{A}
0.105% Citric Acid	6.51 ^{B}	5.12 ^{B}	5.00 ^{B}	3.43 ^{A}	1.82 ^{B}	5.02 ^{B}
0.21% Citric Acid	6.61 ^{B}	5.53 ^{B}	5.29 ^{B}	3.72 ^{A}	2.18 ^{B}	5.52 ^{B}

[1] Hedonic values are based on a nine-point scale (1 = "dislike extremely", 5 = 'neither dislike nor like", 9 = "like extremely").
[2] Flavor description values are based on a nine-point scale (1 = "extremely tart", 5 = 'neither tart nor sweet", 9 = "extremely sweet").
[3] Color values are based on a nine-point scale (1 = "extremely light", 5 = 'neither light nor dark", 9 = "extremely dark").
[4] Texture values are based on a nine-point scale (1 = "extremely brittle", 5 = 'neither brittle nor rubbery", 9 = "extremely rubbery").
A-B means with different superscripts within a sub-column are significantly different ($P<0.05$).

Citric acid has been used for decades to inhibit browning in home-dried fruit (VanGarde and Woodburn, 1994) and may have had an enhancing effect on the blanching treatment used on potato slices. Sapers and Miller (1995) determined that immersion (15-20 min) of pre-peeled potatoes in a heated (45-55°C) citric/ascorbic acid solution (2% and 1%, respectively) prevented discoloration of the peeled surface for up to 14 d at 4°C. In the present study, consumers considered acid blanched potato slices significantly ($P<0.05$) more brittle/hard than slices dried without a treatment. Similarly, toughening was found to be associated with the presence of citric acid in heated solutions used to control discoloration in peeled potatoes and may be related to pectin degradation (Sapers and Miller, 1995). Nevertheless, blanching in 0.105% or 0.21% citric acid prior to dehydration maintained or improved the appearance, flavor acceptability and overall acceptability of dried potato slices.

Physical Analysis. The pH values of untreated (control) carrot (5.35 ± 0.28) and potato slices (5.66 ± 0.23) remained near or within the normal range for carrots and potatoes (5.40-5.80 and 5.40-5.90, respectively) (FDA/CFSAN, 2003; Tassou and Boziaris, 2002) throughout 6 h of dehydration and 30 d of storage (Table A7.2). Carrot slices blanched in 0.105% citric acid (pH 3.08 ± 0.07) or 0.21% citric acid (pH 2.48 ± 0.2) had pH values (4.28-4.47 and 3.87-4.12, respectively) that were significantly ($P<0.05$) lower than the pH values of untreated samples throughout dehydration and storage. Potato slices blanched in 0.105% or 0.21% citric acid had pH values (4.95 ± 0.55 and 4.90 ± 0.63, respectively) that were generally lower than untreated samples throughout dehydration, and significantly ($P<0.05$) lower than untreated samples throughout storage.

Treatment had no effect ($P>0.05$) on the water activity of carrot and potato slices which ranged from 0.98 to 0.99 at 0 h of dehydration (Table A7.2). The water activity of carrot slices ranged from 0.26 to 0.31 immediately following 6 h of dehydration, and increased to 0.34 to 0.37 throughout 30 d of storage regardless of treatment. Similarly, the water activity of all potato samples increased from 0.12 to 0.17 at 6 h of dehydration to 0.12 to 0.47 throughout 30 d of storage. Samples were stored in plastic bags (aerobically) at ambient temperature (25 ± 3°C and 30 ± 6% relative humidity), which may have allowed them to gain moisture during storage. Nevertheless, all carrot and potato samples tested had a water activity below 0.60 following 6 h of dehydration and throughout 30 d of storage and, therefore, would be unlikely to support bacterial growth (Chirife and del Pilar Buera, 1996)

An increasing association between low moisture foods and foodborne infection has lead to concerns about the safety of home-dried foods (CDC, 1995a, b, c; Eidson et al., 2000; Keene et al., 1997; Killalea et al., 1996; Lehmacher et al., 1995; nummer et al., 2004; ProMED-mail, 2003). Research has shown that traditional treatments for drying foods at home may allow survival of pathogens, and that minor modifications in preparation methods reduced survival of bacteria during drying and storage (Albright et al., 2002; Albright et al., 2003; Burnham et al., 2001; Calicioglu et al., 2002a, b; Calicioglu et al., 2003, DiPersio et al., 2003; DiPersio et al., 2004a; DiPersio et al., 2005a, b, c; Yoon et al., 2004). Outcomes of educational workshops indicate improved knowledge and attitude concerning safe food drying methods, which may reinforce adoption of new food drying guidelines by home food preservers. Participants were more likely to practice some safe food drying behaviors, and believed their food drying

practices improved as a direct result of attending the training workshop. Modified treatments, including blanching in a 0.105% or 0.21% citric acid solution before drying, maintained or improved the appearance, flavor and overall acceptability of dehydrated carrot and potato slices. Methods and educational materials are currently being publicized through Cooperative Extension Services, and are available to consumers through educational activities, bulletins, fact sheets and the internet. It is important to note that drying procedures, educational materials and workshops were developed and tested in Colorado and, therefore, may be less relevant to other areas of the country.

CHAPTER VIII

SUMMARY

- Immersing fruit pieces in 3.4% ascorbic acid or 1.7% citric acid solutions before home-type dehydration maintained or improved the appearance and overall acceptability of dehydrated apple slices, banana slices, cantaloupe slices, peach pieces, pear slices and tomato halves. Citric acid was more effective than ascorbic acid at preserving color during the dehydration of peach, banana and tomato samples.

- Cooperative Extension Services personnel recommend blanching or immersion in a sodium chloride solution before drying, or oven heating after drying, to help maintain the quality home-dried vegetables. Treatments did not enhance *Salmonella* reductions during dehydration and storage of carrot slices and, therefore, may not enhance the safety of the product when contaminated.

- Steam blanching (88°C, 10 min), water blanching (88°C, 4 min), blanching in a 0.105% citric acid solution (88°C, 4 min), or blanching in a 0.21% citric acid solution enhanced inactivation of *Salmonella* during dehydration and storage of carrot and potato slices. Consumer evaluations showed treatments maintained or improved the appearance, flavor and overall acceptability of the finished product.

- Guidelines were developed based on work designed to improve the safety of home-dried foods. To encourage adoption of new food drying guidelines, a booklet, *Drying Foods*, and workshop were developed and pilot-tested with extension educators and volunteers. Pre-, post and follow up surveys were developed to assess food drying knowledge, attitudes and behavior. Knowledge and attitude scores regarding safe food drying methods significantly ($P<0.05$) improved pre- to 6 weeks following the intervention. Participants also indicated improvements in food drying practices at the 6-week follow up. Outcomes indicate improved subject knowledge, attitude and behavior, which may reinforce adoption of new food drying guidelines.

RECOMMENDATIONS

More research is needed to understand *Salmonella* survival and growth in dehydrated meats, fruits and vegetables. Follow up studies are needed to evaluate the effect of recommended treatments on pathogen survival in other fruits and vegetables during home-style dehydration and storage. Studies are also needed to evaluate the sensory properties of other fruits and vegetables prepared using recommended treatments prior to dehydration. Objective measurements (color, texture) should be included in future studies. New food drying guidelines must be publicized through Cooperative Extension Services, and information made widely available to consumers through additional training workshops, the *Drying Foods* bulletin and the internet. It is important to note that drying procedures, educational materials and workshops were developed and tested in Colorado and may not be appropriate in other regions. Therefore, similar studies must be conducted throughout the country.

CHAPTER IX

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APPENDICES

Table A.3.1. Mean (n=12) (SD) temperature of Nantes carrot slices and dehydrator air during drying for up to 6 h following inoculation and various treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 3 min), water blanched (88°C, 3 min), or immersed in 3.23% NaCl (25°C, 5 min], and dried for 6 h, or dried for 6 h and oven heated (80°C, 15 min).

Time (h)	Carrot slice temperature (°C)	Dehydrator air temperature (°C)
0	37.1 (5.6)	47.9 (5.5)
0.5	41.7 (3.1)	51.3 (4.7)
1	55.4 (3.9)	55.5 (2.8)
1.5	55.6 (6.7)	59.6 (7.6)
2	60.2 (1.8)	59.2 (1.8)
2.5	60.3 (1.6)	59.8 (1.6)
3	60.5 (1.6)	59.8 (1.2)
3.5	60.2 (1.2)	59.8 (0.7)
4	60.1 (0.7)	59.8 (1.2)
4.5	60.1 (1.2)	60.2 (0.4)
5	59.7 (0.4)	59.5 (0.5)
5.5	60.4 (0.5)	60.0 (0.4)
6	61.4 (0.7)	60.5 (0.4)

Table A3.2. Preparation procedures for home-type dehydration of carrots and potatoes recommended by Cooperative Extension Services[a].

	Preparation Procedures	
State	Carrots	Potatoes
Alaska	Peel and slice; dry 140°F until tough and leathery	none
California, Georgia, South Carolina	Slice 1/8" thick; dry 140°F for 10-12 h	Slice 1/8" thick; dry 140°F for 8-12 h
Colorado	Peel, slice 1/8" thick; dry until tough to brittle	Same as carrots
Florida	Peel, slice 3/8" thick; dry 140°F for 2h then 130°C for 4-8 h	Peel, slice 1/4 -3/8" thick; dry 140°F for 1 h, then 130°F for 6-8 h
Idaho, Oregon, Pennsylvania Washington State	Slice 1/4" thick; dry 140-150°F for 2-3 h, then dry 130-140°F for 7-9 h	Slice 1/4" thick; dry 140-150°F for 2-3 h, then 130-40°F for 5-9h
Illinois	Slice 1/8-1/4" thick; dry 150°F for 1-2 h, then 140°F for 2-10 h (until brittle)	Same as carrots (dry 3-12 h)
Kansas	Slice up to 3/8" thick; dry 145°F for 4-12 h	none
Minnesota	Slice 1/4" thick; dry 140-145°F for 6-8 h	Peel, cut into 1/4-1/2" cubes; dry 140-145°F for 6-8 h
Mississippi	Slice 1/8" thick; dry 160°F until visible moisture is gone, then dry 140°F (total 2-4 h)	none
Missouri,	Peel, slice 1/8" thick; dry 120-140°F for 10-12 h	Peel, slice 1/8" thick; dry 120-140°F for 8-12 h
New Mexico	Slice 1/8" thick; dry 140-150°F until tough to brittle (4-12 h)	Same as carrots (dry 4-12 h)
Ohio	Peel, slice 1/8" thick; dry 140°F until very brittle, deep orange	none
Utah	Slice 1/8" thick; dry 140-160°F for 2.5-4 h	Same as carrots (dry 2.5-4 h)
Virginia	Slice 1/8" thick; dry 140°F for 3.5-5 h	none

[a] Information compiled from 20 sets of U.S. Cooperative Extension Service home vegetable drying recommendations. Indiana, Nevada, New Jersey, North Carolina, North Dakota, Rhode Island and Wyoming Cooperative Extension Services reported that they neither published nor distributed produce drying recommendations.

Table A3.3. Treatments for home-type dehydration of carrots recommended by Cooperative Extension Services[a].

State	Blanching Time (min.) Steam	Water	Salt Water Dip	Oven Heating
Alaska	None	2	none	Reheat 175°F for 10-15 min
California, Missouri	3-3.5	3.5	none	none
Colorado	3-4	4	none	Reheat 150°F for 30 min or 175°F for 15 min
Florida	3-4	none	none	not necessary
Georgia, South Carolina	3-3.5	3.5	none	Reheat 160°F for 30 min
Idaho, Oregon, Pennsylvania, Washington State	3-4	none	Prep. 2-4 Tbsp. salt per 1 gallon water; soak 2-5 min, drain	none
Illinois	1-3min; cold water rinse 1-3 min; drain	none	Prep. 2-4 Tbsp. salt per 1 gallon water; soak 1 min, drain	Reheat 175°F (80°C) for 15 min (door closed)
Kansas	3-5	none	none	none
Minnesota	4	3	none	none
Mississippi	8-10	none	none	Reheat 175°F for 15 min or 160°F for 30 min
New Mexico	3-4	4	none	none
Ohio	3	none	none	none
Utah	3-4	1.5-2	Prep. 4-6 Tbsp. salt per 1 gallon water; soak 10 min	Reheat 150°F for 30 min
Virginia	3-3.5	3.5	none	Reheat 150°F for 30 min or 160°F for 10 min

[a] Information compiled from 20 sets of U.S. Cooperative Extension Service home vegetable drying recommendations. Indiana, Nevada, New Jersey, North Carolina, North Dakota, Rhode Island and Wyoming Cooperative Extension Services reported that they neither published nor distributed produce drying recommendations.

Table A3.4. Treatments for home-type dehydration of potatoes recommended by Cooperative Extension Services[a].

State	Blanching Time (min.) Steam	Water	Salt Water Dip	Oven Heating
Alaska	None	None	none	Same as carrots
California, Missouri	6-8	5-6	none	none
Colorado	7-9	6-7	none	Reheat 150°F for 30 min or 175°F for 15 min
Florida	4-6, rinse in cold water	None	none	not necessary
Georgia, South Carolina	6-8	5-6	none	Reheat 160°F for 30 min
Idaho, Oregon, Pennsylvania, Washington State	6-8	5-6	Same as carrots	none
Illinois	Same as carrots	None	Same as carrots	Same as carrots
Minnesota	5	None	none	none
Mississippi, Ohio	None	None	none	none
New Mexico	7-9	6-7	none	none
Utah	6-8	5-6	Same as carrots	Same as carrots
Virginia	None	None	none	Same as carrots

[a] Information compiled from 20 sets of U.S. Cooperative Extension Service home vegetable drying recommendations. Indiana, Nevada, New Jersey, North Carolina, North Dakota, Rhode Island and Wyoming Cooperative Extension Services reported that they neither published nor distributed produce drying recommendations.

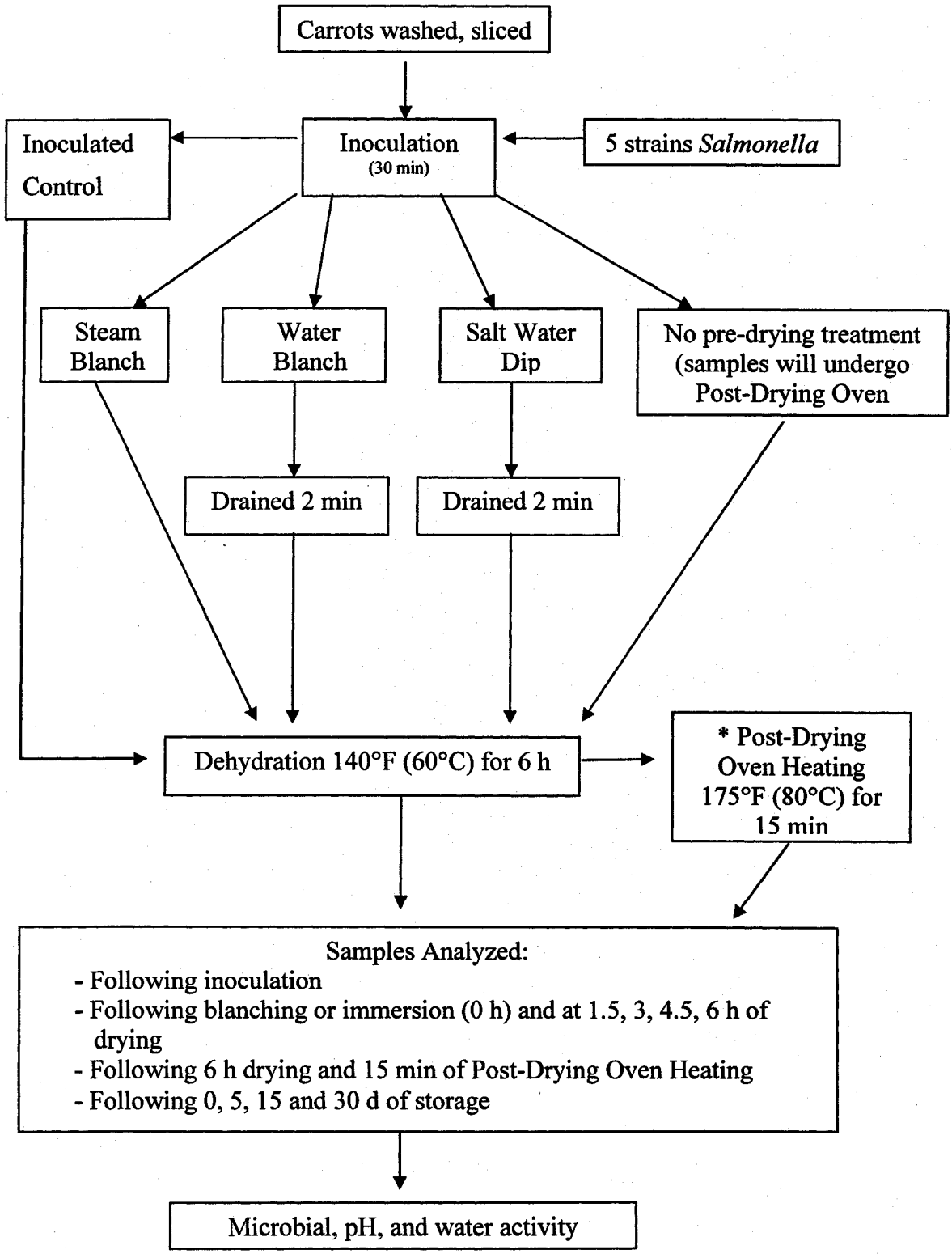


Figure A3.1. Flow diagram for Chapter III.

Table A.4.1. Mean (n=12) (SD) temperature of Nantes carrot slices and dehydrator air during drying for up to 6 h following inoculation and various treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dried for 6 h.

Time (h)	Carrot Slice Temperature (°C)	Dehydrator Air Temperature (°C)
0	36.4 (5.2)	50.5 (2.1)
0.5	39.1 (9.2)	53.1 (0.6)
1	45.5 (4.2)	57.4 (1.1)
1.5	52.0 (9.9)	60.1 (2.7)
2	57.3 (4.5)	60.0 (0.8)
2.5	59.7 (6.3)	60.4 (1.2)
3	58.5 (7.4)	59.8 (1.3)
3.5	58.4 (6.4)	60.4 (2.1)
4	58.0 (7.0)	60.0 (1.3)
4.5	60.1 (2.3)	59.2 (1.3)
5	60.0 (1.9)	59.7 (1.8)
5.5	60.3 (0.6)	59.8 (0.8)
6	60.1 (0.4)	61.4 (1.2)

Table A4.2. Mean[1] (SD) pH of Nantes carrot slices during drying for up to 6 h following inoculation and various treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dried for 6 h at 60°C (140°F).

Processing step	Control[2]	Steam Blanched[3]	Water Blanched[4]	0.105% Citric Acid Blanched[5]	0.21% Citric Acid Blanched[6]
Following inoculation[7]	5.09Aa (0.31)	5.09Aa (0.31)	5.09Aa (0.31)	5.09Aa (0.31)	5.09Aa (0.31)
Following pre-treatment (0 h)	5.09Aa (0.31)	5.12Aa (0.41)	5.24Aa (0.53)	4.31Bb (0.19)	3.87Bb (0.07)
Dehydration (1.5 h)	5.46Aa (0.23)	5.30Aa (0.32)	5.36Aa (0.45)	4.31Bb (0.11)	3.93Bb (0.02)
Dehydration (3 h)	5.48Aa (0.28)	5.31Aa (0.32)	5.39Aa (0.43)	4.28Bb (0.10)	3.97Bb (0.13)
Dehydration (4.5 h)	5.46Aa (0.23)	5.32Aa (0.30)	5.39Aa (0.42)	4.41Bb (0.16)	3.96Bb (0.15)
Dehydration (6 h)	5.44Aa (0.22)	5.30Aa (0.27)	5.35Aa (0.33)	4.31Bb (0.06)	3.90Bb (0.09)

[1] Means represent two samples from three replications (n=6) (LSD = 0.46).
[2] Control, inoculated w/ no pre-treatment, or inoculated and steam blanched [3] (88°C, 10 min), water blanched [4] (88°C, 4 min), blanched in 0.105% citric acid [5] (88°C, 4 min), or blanched in 0.21% citric acid [6] (88°C, 4 min).
[7] Following inoculation (25°C, 30 min attachment time).
A-B means with different letters within a column are significantly different (P<0.05).
a-b means with different letters within a row are significantly different (P<0.05).

Table A4.3. Mean[1] (SD) water activity of Nantes carrot slices during drying for up to 6 h following inoculation and various treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dried for 6 h at 60°C (140°F).

Processing steps	Control[2]	Steam Blanched[3]	Water Blanched[4]	0.105% Citric Acid Blanched[5]	0.21% Citric Acid Blanched[6]
Following inoculation[7]	0.991Aa (0.003)	0.991Aa (0.003)	0.991Aa (0.003)	0.991Aa (0.003)	0.991Aa (0.003)
Following pre-treatment (0 h)	0.991Aa (0.003)	0.983Aa (0.007)	0.985Aa (0.009)	0.980Aa (0.094)	0.982Aa (0.013)
Dehydration (1.5 h)	0.514Ba (0.144)	0.578Bab (0.199)	0.668Bab (0.230)	0.667Bab (0.149)	0.736Bb (0.251)
Dehydration (3 h)	0.383Ca (0.054)	0.389Ca (0.052)	0.427Ca (0.074)	0.540Ba (0.073)	0.444Ca (0.071)
Dehydration (4.5 h)	0.365Ca (0.068)	0.354Ca (0.020)	0.368Ca (0.044)	0.355Ca (0.036)	0.349Ca (0.013)
Dehydration (6 h)	0.328Ca (0.028)	0.333Ca (0.032)	0.341Ca (0.029)	0.342Ca (0.029)	0.325Ca (0.015)

[1] Means represent two samples from three replications (n=6) (LSD = 0.16).
[2] Control, inoculated w/ no pre-treatment, or inoculated and steam blanched [3] (88°C, 10 min), water blanched [4] (88°C, 4 min), blanched in 0.105% citric acid [5] (88°C, 4 min), or blanched in 0.21% citric acid [6] (88°C, 4 min).
[7] Following inoculation (25°C, 30 min attachment time).
A-C means with different letters within a column are significantly different (P<0.05).
a-b means with different letters within a row are significantly different (P<0.05).

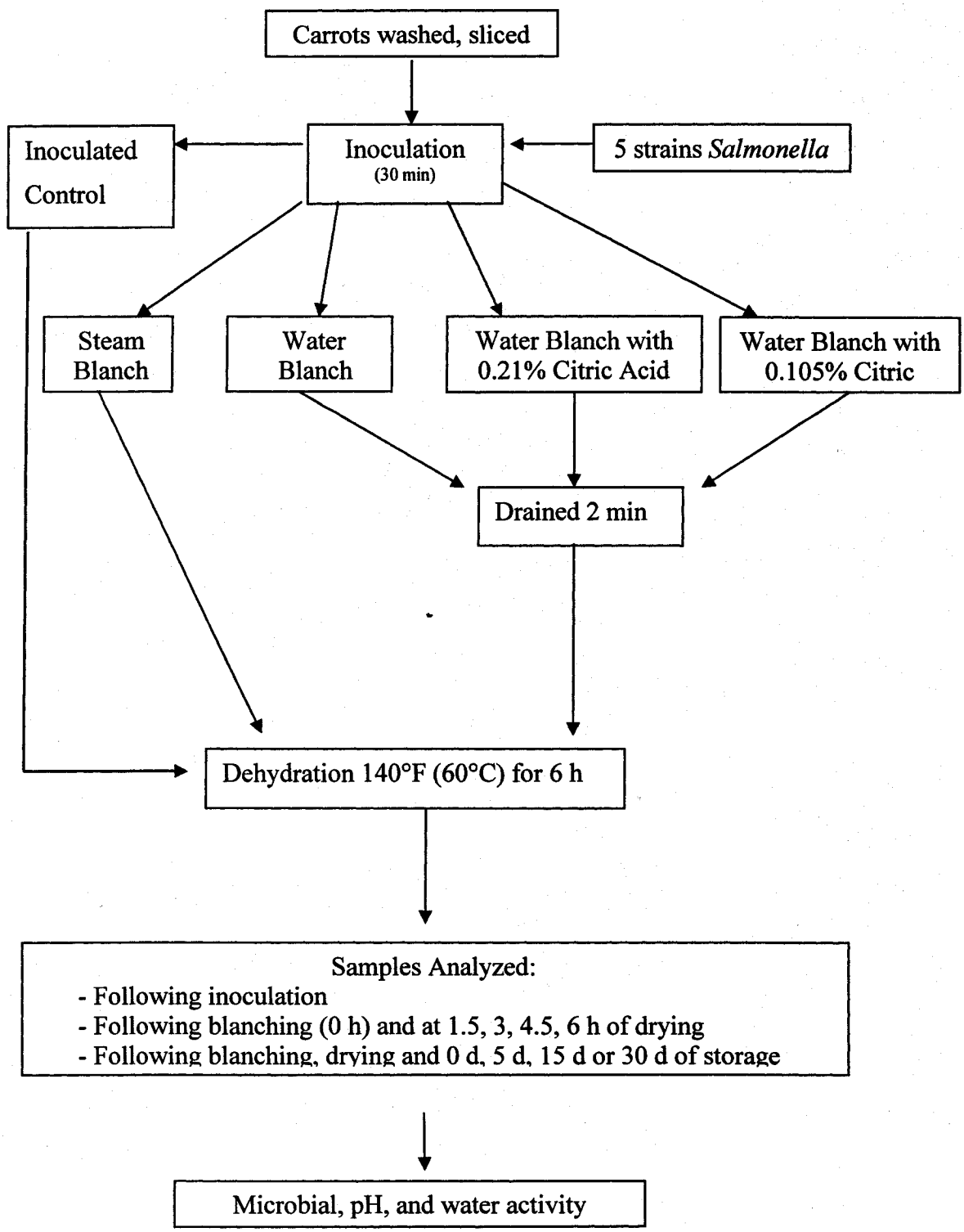


Figure A4.1. Flow diagram for Chapter IV.

Table A.5.1. Mean (n=12) (SD) temperature of Russet potato slices and dehydrator air during drying for up to 6 h following inoculation and various treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dried for 6 h.

Time (h)	Potato Slice Temperature (°C)	Dehydrator Air Temperature (°C)
0	31.9 (12.2)	45.3 (12.0)
0.5	42.5 (17.3)	52.0 (14.9)
1	52.4 (6.2)	56.2 (6.7)
1.5	59.2 (3.2)	59.4 (9.8)
2	62.0 (7.2)	61.0 (6.0)
2.5	61.8 (7.4)	61.2 (6.5)
3	61.7 (2.2)	61.1 (3.5)
3.5	61.4 (3.6)	60.8 (2.1)
4	61.2 (3.0)	60.7 (1.0)
4.5	61.6 (4.2)	60.5 (1.6)
5	61.4 (3.3)	60.7 (3.0)
5.5	61.2 (1.5)	60.9 (3.0)
6	61.1 (2.0)	61.0 (2.1)

Table A5.2. Mean[1] (SD) pH of Russet potato slices during drying for up to 6 h following inoculation and various treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dried for 6 h at 60°C (140°F).

Processing steps	Control[2]	Steam Blanched[3]	Water Blanched[4]	0.105% Citric Acid Blanched[5]	0.21% Citric Acid Blanched[6]
Following inoculation[7]	5.72Aa (0.61)	5.72Aa (0.61)	5.72Aa (0.61)	5.72Aa (0.61)	5.72Aa (0.61)
Following pre-treatment (0 h)	5.72Aa (0.61)	5.61Aab (0.16)	5.61Aab (0.11)	5.11Bb (0.61)	5.10Bb (0.62)
Dehydration (1.5 h)	5.70Aa (0.18)	5.52Aab (0.08)	5.57Aab (0.18)	5.16Bb (0.07)	5.06Bb (0.59)
Dehydration (3 h)	5.71Aa (0.13)	5.49Aab (0.16)	5.52Aab (0.20)	5.14Bb (0.15)	5.08Bb (0.59)
Dehydration (4.5 h)	5.66Aa (0.14)	5.57Aab (0.26)	5.46Aab (0.15)	5.23Bab (0.39)	5.05Bb (0.59)
Dehydration (6 h)	5.63Aa (0.19)	5.52Aab (0.13)	5.52Aab (0.16)	5.18Bab (0.39)	5.04Bb (0.67)

[1] Means represent two samples from three replications (n=6) (LSD = 0.53).
[2] Control, inoculated w/ no pre-treatment, or inoculated and steam blanched [3] (88°C, 10 min), water blanched [4] (88°C, 4 min), blanched in 0.105% citric acid [5] (88°C, 4 min), or blanched in 0.21% citric acid [6] (88°C, 4 min).
[7] Following inoculation (25°C, 30 min attachment time).
A-B means with different letters within a column are significantly different (P<0.05).
a-b means with different letters within a row are significantly different (P<0.05).

Table A5.3. Mean[1] water activity of Russet potato slices during drying for up to 6 h following inoculation and various treatments [inoculated control (25°C, 30 min), steam blanched (88°C, 10 min), water blanched (88°C, 4 min), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dried for 6 h at 60°C (140°F).

Processing steps	Control[2]	Steam Blanched[3]	Water Blanched[4]	0.105% Citric Acid Blanched[5]	0.21% Citric Acid Blanched[6]
Following inoculation[7]	0.990Aa (0.007)	0.990Aa (0.007)	0.990Aa (0.007)	0.990Aa (0.007)	0.990Aa (0.007)
Following pre-treatment (0 h)	0.990Aa (0.007)	0.989Aa (0.001)	0.991Aa (0.008)	0.990Aa (0.007)	0.992Aa (0.004)
Dehydration (1.5 h)	0.622Aa (0.275)	0.835Aa (0.076)	0.821Aa (0.024)	0.860Aa (0.073)	0.710Aa (0.049)
Dehydration (3 h)	0.226Aa (0.032)	0.295Aa (0.086)	0.172Ba (0.015)	0.260Aa (0.151)	0.274Aa (0.159)
Dehydration (4.5 h)	0.163Ba (0.031)	0.170Ba (0.019)	0.145Ba (0.007)	0.170Ba (0.036)	0.181Ba (0.031)
Dehydration (6 h)	0.143Ba (0.021)	0.131Ba (0.009)	0.148Ba (0.033)	0.138Ba (0.011)	0.144Ba (0.021)

[1] Means represent two samples from three replications (n=6) (standard deviation of the replicates) (LSD = 0.08).
[2] Control, inoculated w/ no pre-treatment, or inoculated and steam blanched [3] (88°C, 10 min), water blanched [4] (88°C, 4 min), blanched in 0.105% citric acid [5] (88°C, 4 min), or blanched in 0.21% citric acid [6] (88°C, 4 min).
[7] Following inoculation (25°C, 30 min attachment time).
A-B means with different letters within a column are significantly different (P<0.05).
a means with different letters within a row are significantly different (P<0.05).

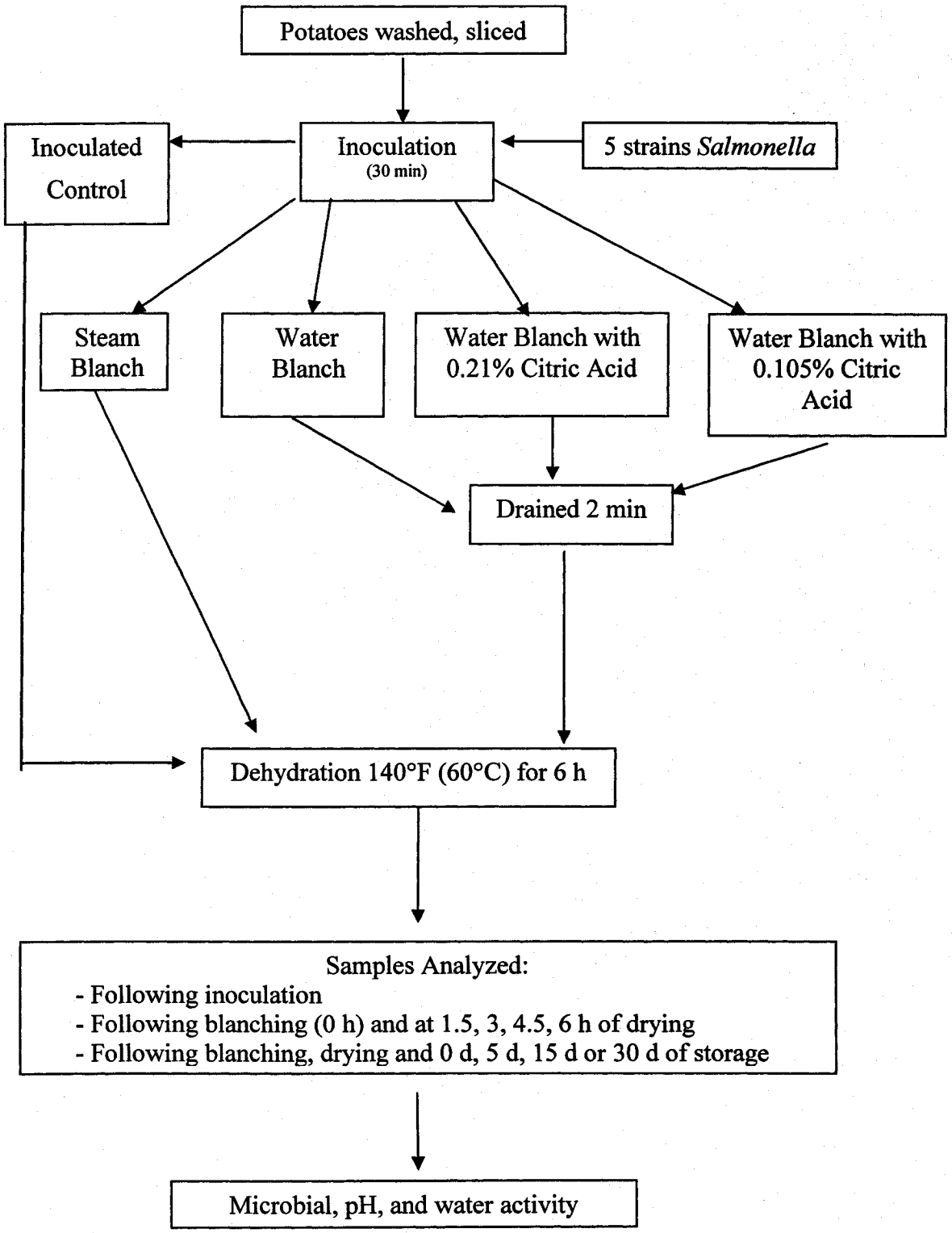


Figure A5.1. Flow diagram for Chapter V.

PROJECT APPROVAL LETTER

Colorado State University

Office of Regulatory Compliance
Office of Vice President for Research
and Information Technology
Fort Collins, CO 80523-2011
(970) 491-1553
FAX: (970) 491-2293

MEMORANDUM

TO: John Sofos, Animal Sciences, 1171

FROM: Janell A. Meldrem, Regulatory Administrator for the Human Research Committee

SUBJECT: **PROJECT APPROVAL**
Title: Minimizing the Risk of Listeria Monocytogenes and Other Pathogens in Dried Food
Protocol No.: 00-187H
Funding Agency: USDA

DATE: July 7, 2004

I am pleased to inform you that the above-referenced project was approved by the Human Research Committee on July 6, 2004 for the period August 6, 2004 to August 6, 2005 with the condition that the attached consent form is signed by the subjects and each subject is given a copy of the form. It is the investigator's responsibility to obtain this consent form from all subjects. *NO changes may be made to this document without first obtaining the approval of the Committee.* **Approval is for the remaining 74 participants.**

A status report of this project will be required within a 12-month period from the date of approval. Renewal is the Principal Investigator's responsibility, but as a courtesy you will be sent a reminder approximately two months before the protocol expires. The Principal Investigator will report on the number of subjects who have participated this year and project-to-date, about problems encountered, and provide a verifying copy of the consent form or cover letter used. The necessary form (H-101) is available from the Regulatory Compliance web page (see below). Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

It is the responsibility of the investigator to immediately inform the Committee of any serious complications, unexpected risks, or injuries resulting from this research. It is also the investigator's responsibility to notify the Committee of any changes in experimental design, participant population, or consent procedures or documents. This can be done with a memo which completely describes the changes and their consequences (new consent form or cover letter, or altered survey instrument, for example). Students serving as Co-Principal Investigators may not alter projects without first obtaining PI approval. The PI is ultimately responsible for the conduct of the project. Upon completion of the project, an H-101 form should be submitted as a close-out report.

This approval is issued under Colorado State University's OHRP Federal Wide Assurance 00000647 issued July 1, 2001. If approval did not accompany a proposal when it was submitted to a sponsor, it is the researcher's responsibility to provide the sponsor with the approval notice.

Please direct any questions about the Committee's action on this project to me for routing to the Committee.

Attachment

COPY

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

ASSURANCE STATEMENT(S)

OMB Approval 0524-0039
Expires 03/31/2004

STATEMENT OF POLICY - Institutions receiving CSREES funding for research are responsible for protecting human subjects, providing humane treatment of animals, and monitoring use of recombinant DNA. To provide for the adequate discharge of this responsibility, CSREES policy requires an assurance by the institution's Authorized Organizational Representative (AOR) that appropriate committees in each institution have carried out the initial reviews of protocol and will conduct continuing reviews of supported projects. CSREES also requires AOR certification by citing a timely date that an appropriate committee issued an approval or exemption.

NOTE: Check appropriate statements, supplying additional information when necessary.

1. INSTITUTION

Colorado State University

2. CSREES PROJECT NUMBER OR AWARD NUMBER (if known)

3. PROJECT DIRECTOR (S)
John Sofos

4. TITLE OF PROJECT
Minimizing the Risk of Listeria Monocytogenes and Other Pathogens in Dried Foods

A. BIOSAFETY OF RECOMBINANT DNA

☒ Project does not involve recombinant DNA.

☐ Project involves recombinant DNA and was either approved ☐ or determined to be exempt ☐ from the NIH Guidelines by an Institutional Biosafety Committee (IBC) on_____(Date).

This performing organization agrees to assume primary responsibility for complying with both the intent and procedures of the National Institutes of Health (NIH), DHHS Guidelines for Research Involving Recombinant DNA Molecules, as revised.

B. CARE AND USE OF ANIMALS

☒ Project does not involve vertebrate animals.

☐ Project involves vertebrate animals and was approved by the Institutional Animal Care and Use Committee (IACUC) on _____ (Date).

This performing organization agrees to assume primary responsibility for complying with the Animal Welfare Act (7 USC, 2131-2156), Public Law 89-544, 1996, as amended, and the regulations promulgated thereunder by the Secretary of Agriculture in 9 CFR Parts 1, 2, 3, and 4. In the case of domesticated farm animals housed under farm conditions, the institution shall adhere to the principles stated in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching, Federation of Animal Science Societies, 1999.

C. PROTECTION OF HUMAN SUBJECTS

☐ Project does not involve human subjects.

☒ Project involves human subjects and

☒ Was approved by the Institutional Review Board (IRB) on July 6, 2004. Performing Institution holds a Federalwide assurance number FWA 00000647; if not, a Single Project Assurance is required.

☐ Is exempt based on exemption number_____.

☐ Specific plans involving human subjects depend upon completion of survey instruments, prior animal studies, or development of material or procedures. No human subjects will be involved in research until approved by the IRB and a revised Form CSREES-2008 is submitted.

This performing organization agrees to assume primary responsibility for complying with the Federal Policy for Protection of Human Subjects as set forth in 45 CFR Part 46, 1991, as amended, and USDA regulations set forth in 7 CFR 1c, 1992. All nonexempt research involving human subjects must be approved and under continuing review by an IRB. If the performing organization submits a Single Project Assurance, supplemental information describing procedures to protect subjects from risks is required.

SIGNATURE OF AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	TITLE	DATE
Janell A. Meldrem Janell Meldrem	**Administrator Regulatory Compliance Office**	**July 7, 2004**

According to the Paperwork Reduction Act of 1995, an agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0524-0039. The time required to complete this information collection is estimated to average .50 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

CSREES-2008 (12/02/00)

Colorado State University Form H-101
STATUS FORM FOR RENEWAL/CHANGE/CLOSE
Research Involving Human Subjects

Return to: Human Research Committee
Regulatory Compliance, 410 University Services Center, 2011

THIS FORM MUST BE LEGIBLE.

1. Principal Investigator: John Sofos
2. Department: Animal Sciences Phone: _____
3. Co-investigator(s): Patricia Kendall
4. Project Title: Minimizing the Risk of Listeria monocytogenes and Other Pathogens in dried Foods
5. Protocol Number: 00-187H Date Approved: 8/05/03 Date activity initiated: _____

COMPLETE BELOW THOSE ITEMS WHICH ARE APPLICABLE TO THIS ACTION.

6. Action:
   - ☐ Close project. Complete #7, 8, 9, 10, and 11 below
   - X Renew project. Complete #7, 8, 9, 10, and 11 below
   - ☐ Change project. Complete #12 below

7. Numbers of subjects:
   approved for: _____ studied last approval year: _____ total studied to date: ____ remaining to study: _____

8. Is the study ongoing as *originally* approved?
   - X Yes.
   - ☐ No. **On separate sheet describe the change(s) with date(s) approved by HRC.**

9. Have any unexpected risks or problems been encountered since the last review?
   - ☐ Yes. Describe the risks or problems encountered in a separate memo.
   - X No.

10. Were any subject(s) withdrawn from this study?
    - ☐ Yes. Describe the reasons for withdrawal in a separate memo.
    - X No.

11. Was a consent form or cover letter required as a part of the original approval?
    - X Yes. **Attach a copy** of the consent form or cover letter used in this study. If renewing, be sure consent form includes all current clauses, phone numbers, and staff changes.
    - ☐ No.

12. For changes: attach a memorandum enumerating changes; include supporting documentation, such as collaborator's letters, and revised consent form(s) as necessary. Revisions may not be implemented until you have received written Human Research Committee approval.

_____ _____
Principal Investigator Date

_____ _____
Department Head (Note if Acting Department Head) Date

H-101 (August 1995)

COLORADO STATE UNIVERSITY
INFORMED CONSENT TO PARTICIPATE IN A RESEARCH PROJECT

TITLE OF PROJECT: Minimizing the Risk of *Listeria monocytogenes* and Other Pathogens in Dried Foods

NAME OF PRINCIPAL INVESTIGATOR: John N. Sofos, Ph.D.

NAME OF CO-INVESTIGATOR: Patricia A. Kendall, Ph.D., R.D., Gary C. Smith, Ph.D.

CONTACT NAME & PHONE NUMBER FOR QUESTIONS/PROBLEMS: Patricia Kendall, 970-491-1945

SPONSOR OF PROJECT: USDA-CSREES

PURPOSE OF THE RESEARCH: This study involves research into minimizing the risk of foodborne pathogens such as *Listeria monocytogenes*, *E. coli* O157:H7 and *Salmonella* in home-dried meats, fruits and vegetables. In 1995, investigators concluded that homemade venison jerky was implicated in an outbreak of *E. coli* O157:H7. Traditional drying methods were used in the preparation of the jerky. This research study is designed to develop safe and consumer acceptable methods of drying foods at home.

PROCEDURES/METHODS TO BE USED: You will taste beef, venison, apples, peaches and/or tomatoes that have been dried using procedures found to adequately destroy any potential disease causing pathogens that might be on the food. You will taste food products containing ingredients all found to be safe by the Food and Drug Administration. These products will be prepared in a classroom-kitchen, used by Colorado State University. It is expected that you evaluate the samples according to appearance, texture, moisture content, flavor, and overall acceptability. The sample testing will not take more than 30 minutes. You will not be videotaped or audiotaped during any tastings.

RISKS INHERENT IN THE PROCEDURES: There are no known risks involved in this research. It is not possible to identify all potential risks in an experimental procedure, but the researcher(s) have taken reasonable safeguards to minimize any known and potential, but unknown, risks. The products to be tested will not be intentionally inoculated.

BENEFITS: You will be able to taste and consume dried meat, fruit and vegetable samples. In addition, you will further research to find consumer acceptable methods of minimizing the risk of *Listeria monocytogenes* and other pathogens in dried food products.

CONFIDENTIALITY: Strict confidentiality of information will be maintained by recording data using sequential numbers to identify the sensory evaluation sheets. Resulting data will be reported in research materials in aggregate. Only the investigators and necessary personnel (graduate student) will have access to the individual sensory evaluation sheets.

LIABILITY:
The Colorado Governmental Immunity Act determines and may limit Colorado State University's legal responsibility if an injury happens because of this study. Claims against the University must be filed within 180 days of the injury.

Questions about subjects' rights may be directed to Celia S. Walker at (970) 491-1563.

PARTICIPATION: Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 2 pages.

_____
Participant name (printed)

_____ _____
Participant signature Date

_____ _____
Witness to signature (project staff) Date

PARENTAL SIGNATURE FOR MINOR

As parent or guardian you authorize _____ (print name) to become a participant for the described research. The nature and general purpose of the project have been satisfactorily explained to you by _____ and you are satisfied that proper precautions will be observed.

_____
Minor's date of birth

_____
Parent/Guardian name (printed)

_____ _____
Parent/Guardian signature Date

Page 2 of 2 Subject initials _____ Date _____

Figure A6.1. Consent form used for sensory evaluation of dehydrated fruits.

Table A6.1. Mean[1] (SD) pH and water activity values for fruit pieces left untreated (control) or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid and dried for at 60°C (140°F) for 6 h (apple slices, banana slices, cantaloupe slices, peach slices and pear slices), 14 h (tomato halves) or 22 h (peach quarters).

	Control[2]		3.4% Ascorbic Acid[3]		1.7% Citric Acid[4]	
	pH	Water Activity	pH	Water Activity	pH	Water Activity
Apple Slices	4.50A (0.08)	0.278a (0.011)	4.10B (0.06)	0.282a (0.010)	3.88C (0.07)	0.244b (0.017)
Banana Slices	5.61A (0.04)	0.400a (0.023)	4.84B (0.02)	0.427a (0.031)	4.62C (0.04)	0.382a (0.021)
Cantaloupe Slices	6.64A (0.02)	0.385b (0.052)	4.42B (0.05)	0.491a (0.053)	4.40B (0.02)	0.427a (0.052)
Peach Slices	4.08A (0.01)	0.282a (0.024)	3.94AB (0.12)	0.333a (0.009)	3.79B (0.06)	0.294a (0.076)
Peach Quarters	4.30A (0.12)	0.553a (0.091)	4.07A (0.45)	0.463b (0.115)	3.39A (0.27)	0.510b (0.118)
Pear Slices	5.59A (0.10)	0.411a (0.034)	4.82B (0.09)	0.441a (0.033)	4.13C (0.11)	0.445a (0.040)
Tomato Halves	4.53A (0.02)	0.454a (0.037)	4.26B (0.22)	0.464a (0.065)	4.22B (0.16)	0.45a (0.036)

[1] Means represent two samples from three replications (n=6).
[2] Control (no pre-treatment) before dehydration (6 h, 60°C).
[3] Immersed (25°C, 10 min) in a 3.4% ascorbic acid solution before dehydration (6 h, 60°C).
[4] Immersed (25°C, 10 min) in a 1.7% citric acid solution before dehydration (6 h, 60°C).
A-B mean pH values with different letters within a row are significantly different ($P<0.05$).
a-b mean water activity values with different letters within a row are significantly different ($P<0.05$).

Dried Fruit Sensory Evaluation Consumer #: _____

1. Please circle the appropriate responses to the following questions.

Gender : Male Female
Status : Faculty Staff Student Other
Age : Under 21 years old 21 to 34 years old Over 34 years old

Have you ever dried fruit at home? Yes No

Do you like to eat dried fruit? Yes No

How often do you eat dried fruits? Once/week or more 1-3 times/month 1-6 times/year Never **(alone or as part of a trail/snack mix)**

How often do you purchase dried fruits? Once/week or more 1-3 times/month 1-6 times/year Never **(alone or as part of a trail/snack mix)**

2. Score each sample for the attributes listed below by circling the number that represents your rating of the sample. Please cleanse palate with crackers and water between tasting samples.

	Sample:								
Appearance:	1 Dislike Extremely	2	3	4	5 Neither Dislike nor Like	6	7	8	9 Like Extremely
Flavor Description:	1 Dislike Extremely	2	3	4	5 Neither Dislike nor Like	6	7	8	9 Like Extremely
Flavor Acceptability:	1 Dislike Extremely	2	3	4	5 Neither Dislike nor Like	6	7	8	9 Like Extremely
Color:	1 Extremely Light	2	3	4	5 Neither Light nor Dark	6	7	8	9 Extremely Dark
Texture:	1 Extremely Brittle/Hard	2	3	4	5 Neither Brittle nor Soft	6	7	8	9 Extremely Soft
Overall Acceptability:	1 Dislike Extremely	2	3	4	5 Neither Dislike nor Like	6	7	8	9 Like Extremely

Comments:

Figure A6.2. Sensory evaluation form for dehydrated fruits.

Table A6.2. Demographic characteristics of participants (n = 97) in sensory evaluation of peach quarters and peach slices left untreated (control) or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid and dried at 60°C (140°F).

Characteristic	n	%
Gender		
Female	75	77.3
Male	22	22.7
Age		
<21 yr	14	14.4
21 to 34 yr	64	66.0
>34 yr	19	19.6
Status		
Student	80	82.5
Faculty	9	9.3
Staff	5	5.2
Other	3	3.1
Have you ever dried fruits (slices/pieces) at home?		
Yes	22	22.7
No	75	77.3
Do you like to eat dried fruits?		
Yes	78	82.1
No	17	17.9
How often do you eat dried fruits (alone or as part of a trail/snack mix)?		
Never	23	23.7
1-6 times/yr	63	65.0
1-3 times/month	11	11.3
How often do you purchase dried fruits?		
Never	40	41.2
1-6 times/yr	48	49.5
1-3 times/month	9	9.3

Table A6.3. Demographic characteristics of participants (n = 40) in sensory evaluation of pear slices and cantaloupe slices left untreated (control) or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid and dried for 6 h at 60°C (140°F).

Characteristic	n	%
Gender		
Female	29	72.5
Male	11	27.5
Age		
<21 yr	13	32.5
21 to 34 yr	23	57.5
>34 yr	4	10.0
Status		
Student	28	70.0
Faculty	6	15.0
Staff	4	10.0
Other	2	5.0
Have you ever dried fruits (slices/pieces) at home?		
Yes	8	20.0
No	32	80.0
Do you like to eat dried fruits?		
Yes	28	70.0
No	12	30.0
How often do you eat dried fruits (alone or as part of a trail/snack mix)?		
Never	14	35.0
1-6 times/yr	23	57.5
1-3 times/month	3	7.5
How often do you purchase dried fruits?		
Never	19	47.5
1-6 times/yr	19	47.5
1-3 times/month	2	5.0

Table A6.4. Demographic characteristics of participants (n = 93) in sensory evaluation of apple slices and tomato halves left untreated (control) or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid and dried at 60°C (140°F).

Characteristic	n	%
Gender		
Female	64	68.8
Male	29	31.2
Age		
<21 yr	22	23.7
21 to 34 yr	53	57.0
>34 yr	18	19.4
Status		
Student	72	77.4
Faculty	8	8.6
Staff	11	11.8
Other	2	2.2
Have you ever dried fruits (slices/pieces) at home?		
Yes	9	9.7
No	84	90.3
Do you like to eat dried fruits?		
Yes	44	47.3
No	49	52.7
How often do you eat dried fruits (alone or as part of a trail/snack mix)?		
Never	44	47.3
1-6 times/yr	34	36.6
1-3 times/month	15	16.1
How often do you purchase dried fruits?		
Never	58	62.4
1-6 times/yr	27	29.0
1-3 times/month	8	8.6

Table A6.5. Demographic characteristics of participants (n = 40) in sensory evaluation of banana slices left untreated (control) or immersed (10 min, 25°C) in 3.4% ascorbic acid or 1.7% citric acid and dried for 6 h at 60°C (140°F).

Characteristic	n	%
Gender		
Female	38	95.0
Male	2	5.0
Age		
<21 yr	33	82.5
21 to 34 yr	7	17.5
Status		
Student	22	55.0
Staff	14	35.0
Other	4	10.0
Have you ever dried fruits (slices/pieces) at home?		
Yes	17	42.5
No	23	57.5
Do you like to eat dried fruits?		
Yes	30	75.0
No	10	25.0
How often do you eat dried fruits (alone or as part of a trail/snack mix)?		
Never	9	22.5
1-6 times/yr	26	65.0
1-3 times/month	5	12.5
How often do you purchase dried fruits?		
Never	13	32.5
1-6 times/yr	21	52.5
1-3 times/month	6	15.0

COLORADO STATE UNIVERSITY
INFORMED CONSENT TO PARTICIPATE IN A RESEARCH PROJECT

TITLE OF PROJECT: Minimizing the Risk of *Listeria monocytogenes* and Other Pathogens in Dried Foods

NAME OF PRINCIPAL INVESTIGATOR: John N. Sofos, Ph.D.

NAME OF CO-INVESTIGATOR: Patricia A. Kendall, Ph.D., R.D., Gary C. Smith, Ph.D.

CONTACT NAME & PHONE NUMBER FOR QUESTIONS/PROBLEMS: Patricia Kendall, 970-491-1945

SPONSOR OF PROJECT: USDA-CSREES

PURPOSE OF THE RESEARCH: This study involves research into minimizing the risk of foodborne pathogens such as *Listeria monocytogenes*, *E. coli* O157:H7 and *Salmonella* in home-dried meats, fruits and vegetables. In 1995, investigators concluded that homemade venison jerky was implicated in an outbreak of *E. coli* O157:H7. Traditional drying methods were used in the preparation of the jerky. This research study is designed to develop safe and consumer acceptable methods of drying foods at home and to develop educational materials and training programs designed to promote safe drying methods.

PROCEDURES/METHODS TO BE USED: Participants will meet at the pre-determined time and location to participate in the following activities:

1. Food Safety Class: Participate in a pilot training program on safe food drying. Complete pre- and post surveys, and taste dried foods prepared using recommended procedures.

2. Evaluation of Materials: Provide opinions about printed education materials on safe preparation and handling of dried foods, and on motivators and barriers to adopting new drying recommendations developed by the research team.

3. Taste Panel: Taste vegetables that have been dried using procedures found to adequately destroy any potential disease causing pathogens that might be on the food. Taste food products containing ingredients all found to be safe by the Food and Drug Administration. These products will be prepared in a classroom-kitchen, used by Colorado State University. It is expected that you evaluate the samples according to appearance, texture, moisture content, flavor, and overall acceptability. The sample testing will not take more than 30 minutes. You will not be videotaped or audiotaped during any tastings.

Time involved: The food safety class, evaluation of materials and taste panel will take up to 2 hours.

RISKS INHERENT IN THE PROCEDURES: There are no known risks involved in this research. It is not possible to identify all potential risks in an experimental procedure, but the researcher(s) have taken reasonable safeguards to minimize any known and potential, but unknown, risks. The products to be tested will not be intentionally inoculated. It is not anticipated that any of the questions asked in either the survey or educational materials will lead to emotional distress (i.e., fear of preparing or consuming dried foods); however, it is possible that some unforeseen emotional distress could occur. If you are uncomfortable for any reason, you have the option to leave the class at any time.

BENEFITS: You will be able to taste and consume dried food samples. In addition, you will further research to find consumer acceptable methods of minimizing the risk of *Listeria monocytogenes* and other pathogens in dried food products. We hope you will find the education materials provided to be useful to you.

CONFIDENTIALITY: Strict confidentiality of information will be maintained by recording data using sequential numbers to identify the sensory evaluation sheets. Resulting data will be reported in research materials in aggregate. Only the investigators and necessary personnel (graduate student) will have access to the individual sensory evaluation sheets and surveys.

LIABILITY: The Colorado Governmental Immunity Act determines and may limit Colorado State University's legal responsibility if an injury happens because of this study. Claims against the University must be filed within 180 days of the injury. Questions about subjects' rights may be directed to Celia S. Walker at (970) 491-1563.

PARTICIPATION: Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 2 pages.

_____	_____	_____
Participant name (printed)	Participant signature	Date
_____		_____
Witness to signature (project staff)		Date

PARENTAL SIGNATURE FOR MINOR

As parent or guardian you authorize _____ (print name) to become a participant for the described research. The nature and general purpose of the project have been satisfactorily explained to you by _____ and you are satisfied that proper precautions will be observed.

_____	_____	_____	_____
Minor's DOB	Parent/Guardian name (printed)	Parent/Guardian signature	Date

Page 2 of 2 Subject initials _____ Date _____

Figure A7.1. Consent form used for drying foods workshop.

Pre-Workshop Survey

Date:_____ **Workshop Location:**_____

ID: First two letters of mother's name __ __ Last two numbers of birth year ___ ___

Please check whether you agree or disagree with the following statements:

Agree Disagree

___A ___D Foodborne illness outbreaks have been associated with beef jerky and venison jerky.

___A ___D I don't think it's important to monitor oven temperature throughout food food drying.

___A ___D I don't think it's important to monitor dehydrator temperature throughout food drying.

___A ___D I don't worry that jerky may be contaminated with microorganisms and make me sick.

___A ___D I don't worry that dried fruits and vegetables may be contaminated with microorganisms and make me sick.

___A ___D Microorganisms are not able to grow or survive on dried fruits and vegetables.

___A ___D In the past 15 years, the number of produce-associated foodborne illness outbreaks per year has decreased.

___A ___D I am not concerned about case-hardening of meats during drying.

___A ___D I am not concerned about case-hardening of fruits and vegetables during drying.

___A ___D To maintain the best flavor and quality, store jerky in the refrigerator or freezer.

___A ___D Dipping fruits in a solution containing ascorbic acid (Vitamin C), citric acid, or lemon juice may help enhance the destruction of microorganisms during drying.

___A ___D Steam blanching vegetables before drying effectively enhances destruction of microoganisms.

___A ___D Water blanching vegetables before drying effectively enhances destruction of microorganisms.

___A ___D Sun/solar drying is a safe way to dry meats.

___A ___D Sun/solar drying is a safe way to dry fruits and vegetables.

___A ___D I don't think it's important to store dried meats (jerky) in airtight containers.

___A ___D I don't think it's important to store dried produce in airtight containers.

___A ___D I think it is better to dry foods in a food dehydrator than in the oven.

___A ___D I think it is important to condition dried meat before packing for storage.

___A ___D Dried fruits and vegetables should never be conditioned before storage.

Please circle the response that most closely represents you.

	Extremely Unsafe		**Somewhat Safe**		**Extemely Safe**	
1. I would rate my food drying practices as:	1	2	3	4	5	NA
	I don't usually do this		**I Sometimes do this**		**I have always done this**	
2. Thermometer use:						
A) I use a thermometer to monitor dehydrator temperature during drying:	1	2	3	4	5	NA
B) I use a thermometer to monitor oven temperature during drying:	1	2	3	4	5	NA

3. Do you dry meat slices? ____ NO ____ YES

*If you do **not** dry meat slices, skip to question **4***

If you dry meat slices, once they are prepared, do you do any of the following before drying:

	I don't usually do this		**I Sometimes do this**		**I have always done this**
A) I do nothing:	1	2	3	4	5
B) I cook meat slices to 160°F:	1	2	3	4	5
C) I treat meat slices with pickling spices, then a hot pickling brine:	1	2	3	4	5
D) I marinade the meat slices:	1	2	3	4	5
E) I dip meat slices in vinegar, then marinade:	1	2	3	4	5

4. Do you dry fruits such as apple and peach slices/pieces? ____ NO ____ YES

*If you do **not** dry fruits such as apple and peach slices/pieces,skip to question 5*

If you do dry fruits such as apple and peach slices/pieces, once they are prepared, do you do any of the following before drying:

	I don't usually do this		**I Sometimes do this**		**I have always done this**
A) I do nothing:	1	2	3	4	5
B) I dip the fruit in a solution of half lemon juice/half water:	1	2	3	4	5
C) I dip the fruit in a citric acid solution:	1	2	3	4	5
D) I dip the fruit in an ascorbic acid/Vitamin C solution:	1	2	3	4	5
E) I dip fruit in a sulfite solution:	1	2	3	4	5

5. Do you dry vegetables such as carrot slices? ____ NO ____ YES

*If you do **not** dry vegetables such as carrot slices,skip to question 6*

If you do dry vegetables such as carrot slices, once they areprepared, do you do any of the following before drying:

	I don't usually do this		**I Sometimes do this**		**I have always done this**
A) I do nothing:	1	2	3	4	5
B) I steam blanch the slices:	1	2	3	4	5
C) I water blanch the slices:	1	2	3	4	5
D) I water blanch the slices in a citric acid solution:	1	2	3	4	5

Demographic Information:

6. Are you (*check all that apply):*

____ of Hispanic Origin (Mexican, Hispanic, Latino) ____ White, Caucasian

____ Asian or Pacific Islander ____ Mixed Race, Other

____ Black, African American

7. What is your age? ____ Years

8. Are you: ____ Female ____ Male

9. Please identify your affiliations/occupations (*check all that apply*):

____ Master Food Preserver ____ Consumer

____ 4H Leader/Volunteer ____ Other:_____

____ Cooperative Extension Agent

10. Did you dry foods in the last year? ____ Yes ____ No ____ Not Sure

If Yes, check which types: ____ Meats ____ Fruits/Leathers

____ Vegetables ____ Herbs ____ Other_____

11. Did you dry foods in the last **5** years?____ Yes ____ No ____ Not Sure

If Yes, check which types: ____ Meats ____ Fruits/Leathers

____ Vegetables ____ Herbs ____ Other_____

Figure A7.2. Pre-workshop survey.

Post-Workshop Survey

Date:_____ **Workshop Location:**_____

ID: First two letters of mother's name __ __ Last two numbers of birth year ___ ___

Please check whether you agree or disagree with the following statements:

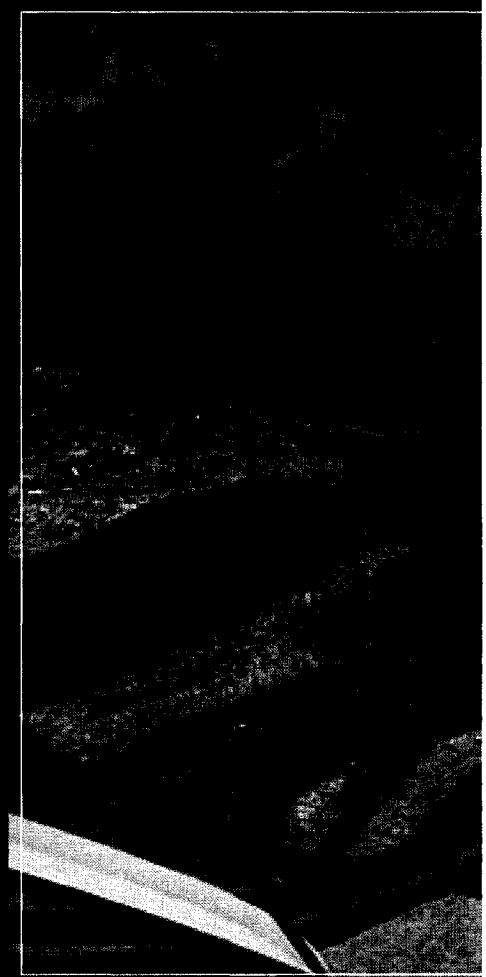
Agree Disagree

___A ___D Foodborne illness outbreaks have been associated with beef jerky and venison jerky.
___A ___D I don't think it's important to monitor oven temperature throughout food food drying.
___A ___D I don't think it's important to monitor dehydrator temperature throughout food drying.
___A ___D I don't worry that jerky may be contaminated with microorganisms and make me sick.
___A ___D I don't worry that dried fruits and vegetables may be contaminated with microorganisms and make me sick.
___A ___D Microorganisms are not able to grow or survive on dried fruits and vegetables.
___A ___D In the past 15 years, the number of produce-associated foodborne illness outbreaks per year has decreased.
___A ___D I am not concerned about case-hardening of meats during drying.
___A ___D I am not concerned about case-hardening of fruits and vegetables during drying.
___A ___D To maintain the best flavor and quality, store jerky in the refrigerator or freezer.
___A ___D Dipping fruits in a solution containing ascorbic acid (Vitamin C), citric acid, or lemon juice may help enhance the destruction of microorganisms during drying.
___A ___D Steam blanching vegetables before drying effectively enhances destruction of microoganisms.
___A ___D Water blanching vegetables before drying effectively enhances destruction of microorganisms.
___A ___D Sun/solar drying is a safe way to dry meats.
___A ___D Sun/solar drying is a safe way to dry fruits and vegetables.
___A ___D I don't think it's important to store dried meats (jerky) in airtight containers.
___A ___D I don't think it's important to store dried produce in airtight containers.
___A ___D I think it is better to dry foods in a food dehydrator than in the oven.
___A ___D I think it is important to condition dried meat before packing for storage.
___A ___D Dried fruits and vegetables should never be conditioned before storage.

Figure A7.3. Post workshop survey.

DRYING FOODS BULLETIN

DRYING *Foods*



Dehydrating Fruits, Vegetables, Leathers and Jerkies

Colorado State University Cooperative Extension

Putting Knowledge to Work

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Drying Foods

Dehydrating Fruits, Vegetables, Leathers and Jerkies

Bulletin 575A

by
[1]P.A. DiPersio, P.A. Kendall, and J.N. Sofos

In 2000, Colorado State University received funding from the U.S. Department of Agriculture and the Colorado Agricultural Experiment Station to conduct work to develop safe and acceptable recommendations for home food drying. This publication is the result of that research.

[1]P.A. DiPersio, M.S., R.D., Colorado State University Department of Food Science and Human Nutrition, Ph.D. candidate, P. A. Kendall, Ph.D., R.D., Colorado State University Cooperative Extension Food Science and Human Nutrition Specialist and Professor, Department of Food Science and Human Nutrition; J. N. Sofos, Ph.D., Colorado State University Professor, Department of Animal Sciences.

Introduction

Drying is one of the oldest and most common forms of food preservation. Dried fruits and meats are healthy snacks, while dried vegetables are often rehydrated and added to other foods. Though dried foods are healthy snacks, and their light weight makes them suitable for sack lunches and backpacking, the reason most foods are dried is to extend shelf life by slowing spoilage due to bacteria, yeasts and molds.

Food drying is based on removing moisture, thus delaying spoilage during storage. The water content of dried foods is 5 percent to 25 percent depending on the food.

Proper drying depends on:

- enough heat to draw moisture out of the food without cooking the food;
- dry air to absorb the moisture; and
- good air circulation to carry off moisture.

Drying is a simple method of food preservation, but the process is not exact. In the past, 'trial and error' was generally used to develop recommended methods. In recent years, however, several food borne disease outbreaks associated with home and commercially prepared jerky have occurred. These have raised concerns about the potential safety of traditional methods of drying both jerky and other foods in the home.

Drying Time and Temperature

The drying process should remove moisture from the food at a temperature that does not harm the flavor, texture and color of the food. If food is heated too fast, case hardening will occur. Case hardening is when the outer layer of the food dries too quickly, a barrier forms and further moisture cannot be released from the inner part of the food. If the temperature is too low during drying, harmful bacteria may survive or even grow during storage. Temperatures of 140° to 145°F are generally recommended for home food drying. The time needed to adequately dry foods will depend on the equipment used, the air dryness and the amount and thickness of the pieces dried.

Note: For food safety and quality reasons, do not use microwave drying, open air (room) drying or sun (solar) drying.

Equipment

Dehydrators. It's best to use thermostatically-controlled electric dehydrators for home food drying. Select dehydrators that have controlled heat settings and fans that blow warm air over the food. Some models have a heat source at the bottom and trays stacked above the heat source. You can buy home food dehydrators at kitchen supply stores for $30 to $200. Air temperature may vary during drying, even in dehydrators with controlled heat settings.

Use a calibrated thermometer throughout food drying to monitor the temperature of the dehydrator. Oven or handheld thermometers may be used. Place an oven thermometer on the center tray of the dehydrator, or insert it through the opening at the center of the drying trays (at an angle so the tip rests on the center tray, not on the heat source). Follow packaging instructions for use of handheld thermometers. Check the temperature every two hours or so. See *Thermometers* section.

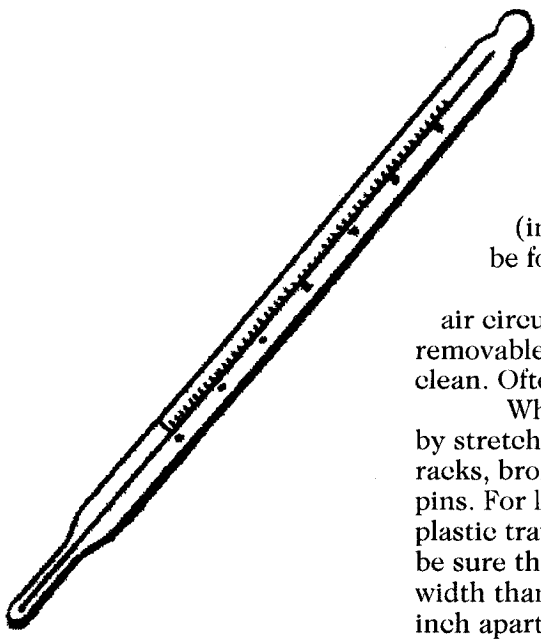
Use the dehydrator indoors in a dry, well-ventilated room. Because food on trays near the heat source will often dry more quickly than food on higher trays, rotate trays during drying. See *Drying Trays* section.

As food dries, it will shrink and you may be tempted to add more food to the dehydrator. Adding food lengthens drying time and is not recommended. It is best to wait until the first batch of food is dried before starting a second batch.

Ovens. If you do not have a dehydrator, a gas or electric oven may be used to dry foods. Watch both carefully to ensure proper drying. To oven dry, preheat oven at lowest setting (140° to 145°F). Adjust the thermostat and prop the oven door open for a consistent temperature and to let moist air escape.

Use a calibrated oven thermometer to be sure oven temperature is 140° to 145°F throughout drying. Place the oven thermometer on the oven rack or tray and check it every two hours during drying. For proper use of handheld thermometers, follow packaging instructions. Also see *Thermometers* section.

Place trays of prepared food in oven. Stack trays so there is at least three inches of clearance at the top and bottom of the oven and 2½ inches between trays. Blocks of wood can be used as pillars between trays. Shift trays, top to bottom and front to back, every hour or so. Stir food often if it is ½-inch deep or more. Single, shallow layers need no stirring. Food may scorch toward the end of drying; therefore, turn the heat off when drying is almost complete and open the door wide for another hour or so. Also see *Drying Trays* section.



Thermometers. Use a calibrated thermometer to monitor temperature throughout drying. Remember, a too-low temperature at the start of drying may cause food to sour or spoil during storage. A too-high temperature during drying may allow harmful organisms to survive.

Oven thermometers cost from $8 to $30. Handheld (infrared) thermometers cost more ($50 to $200). Both can be found at kitchen supply stores.

Drying Trays. Drying trays may be bought or built. Good air circulation is very important. Most food dehydrators come with removable, slotted trays (for air circulation) that are easy to load and clean. Often you can buy extra trays.

When drying small amounts of food in the oven, trays made by stretching cheesecloth or synthetic netting over oven racks, cake racks, broiler racks or cookie sheets work well. Attach with clothes pins. For larger drying projects, use shallow wooden or oven-safe plastic trays with slatted or woven bottoms. For good air circulation, be sure that tray frames are at least 1½ inches smaller in length and width than the oven. Use thin wooden slats or dowels placed ¼ to ½ inch apart, strong curtain netting, or stainless steel screening for tray bottoms.

Do not use galvanized screening for tray bottoms. It has been treated with zinc and cadmium, which can react with some foods. Do not use other metals, such as aluminum, as trays. They may discolor and corrode with use. If used, line with cheesecloth or synthetic netting to keep food from touching the metal. A liner also helps keep foods from sticking to trays and falling through slots.

Lining trays with foil or plastic for easy cleanup is not a good practice since it restricts air flow; the exception is fruit leathers that must be dried on a solid surface.

Wash trays in hot, sudsy water with a stiff brush. Rinse in clear water and air dry thoroughly before and after each use. A light coat of fresh vegetable oil or nonstick spray helps protect trays and makes cleaning easier.

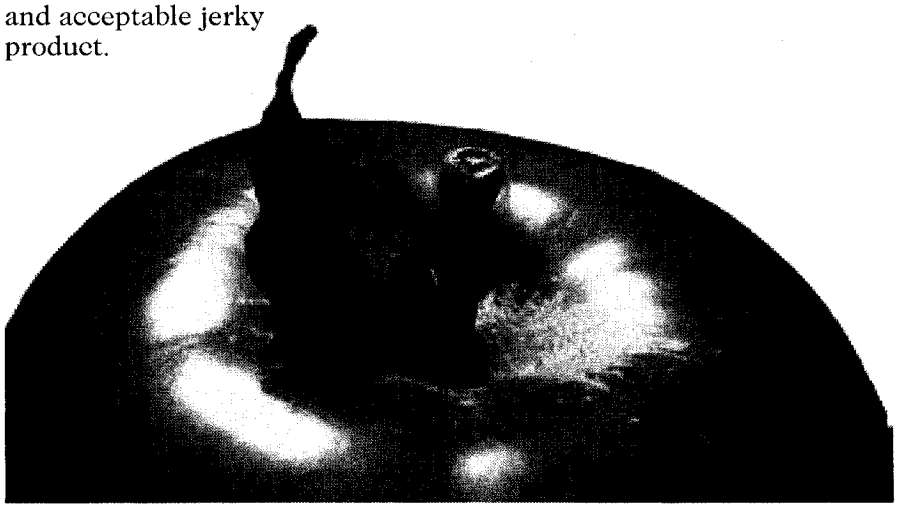
Drying Meats

Jerky is made by drying thin strips of lean meat to about one-fourth its original weight. In the past, recommendations for making jerky were quite general and included drying in the sun, oven or dehydrator. Sun drying is not recommended due to the lack of a controlled heat source and possible contamination from air, animals, bacteria and insects.

Although drying in a dehydrator or oven allows for a safer product, illnesses due to *Salmonella* and *Escherichia coli* O157:H7 in homemade jerky have raised questions about the safety of all methods of drying jerky at home.

E. coli O157:H7 is a dangerous pathogen, especially for the young, elderly or immuno-compromised. Only a few cells can make you sick, thus raising concerns for foods consumed raw or under-cooked. *E. coli* O157:H7 can adapt to acidic conditions and survive for many weeks on dry surfaces and in the refrigerator. Thus, *E. coli* O157:H7 may survive in dried foods.

One method used to destroy *E. coli* O157:H7 during jerky preparation is to pre-cook the meat to 160°F before drying. This method is recommended by the Meat and Poultry Hotline (1-800-535-4555) of the U.S. Department of Agriculture (USDA). However, pre-cooking creates a product that is different than traditional jerky and may not be well liked by consumers. Also, the product may not dry evenly because of case-hardening on the outside surface. The two methods recommended in this bulletin were found to produce a safe and acceptable jerky product.



Drying Produce

Produce used for drying should be the proper size and ripeness, free of wounds, bruises or molds, and cleaned thoroughly before dehydration. Bruised or wounded produce is susceptible to pathogens. Pre-treating fruits with organic acid solutions, such as lemon juice or an ascorbic acid solution, and blanching vegetables helps maintain color and quality. Pre-treatments also maximize the destruction of pathogens and improve the safety and quality of the food throughout drying and storage. See the sections on drying different foods to learn more about pre-treatment methods.

Nutritional Value of Dried Produce

Like all methods of preservation, drying causes some nutrient loss. Changes that may occur during drying include:

- **Calories:** do not change, but are concentrated in a smaller mass as moisture is removed.
- **Fiber:** no change.
- **Vitamin A:** retained under controlled heating.
- **Vitamin C:** mostly destroyed during blanching and drying. Organic acid pre-treatments offset losses.
- **Thiamin, riboflavin, niacin:** some loss during vegetable blanching but fairly good retention if the water used to rehydrate is consumed.
- **Minerals:** some may be lost during rehydration if the water used to rehydrate the dried food is not used; iron is not lost.
- **For best retention of nutrients** in dried foods, store in a cool, dark, dry place, or in the refrigerator or freezer, and use within a year.

Drying Fruits

Selecting and Preparing Fruits

See Table 1 for yields of dried fruits. Choose fresh and ripe fruits. Immature produce lacks flavor and color. Overripe produce can be tough and fibrous or soft and mushy. Drying does not improve food quality.

Thoroughly wash and clean fruits to remove dirt, bacteria or residues. Sort and discard any fruit that shows decay, bruises or mold. Such defects can affect all foods being dried. Peel, cut and slice fruit as recommended in Table 2.

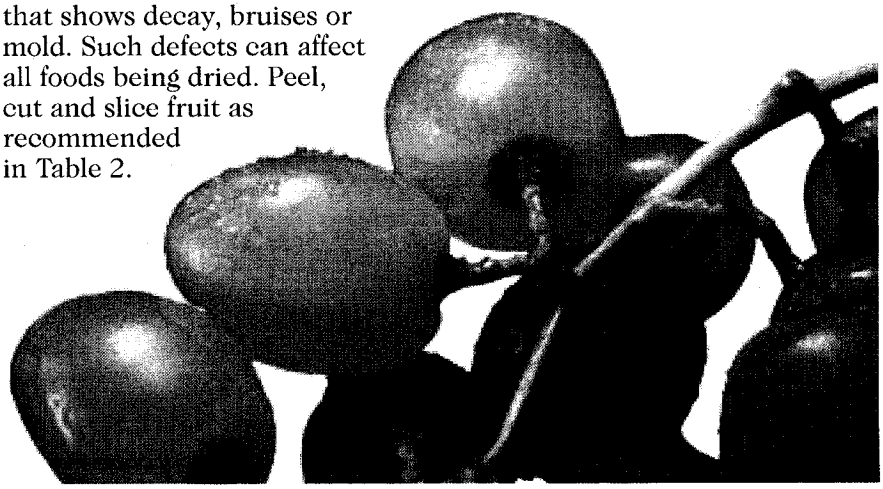


Table 1. Yield of dried fruits

Produce	Amount picked or purchased	Amount dried product	
	Pounds	Pounds	Pints
Apples	12	1¼	3
Grapes	12	2	3
Peaches	12	1 to 1½	2 to 3
Pears	14	1½	3
Tomatoes	14	½	2½ to 3

Source: Drying Foods at Home, Marjorie M. Philip. Cooperative Extension Service. University of Arkansas, Little Rock, Arkansas 72203.

Treating Fruits for Quality and Safety

Treating fruits before drying is highly recommended. It helps keep light-colored fruits from darkening during drying and storage, and speeds drying of some fruits, such as grapes and cherries. Research shows that treating with an acidic solution or sodium metabisulfite dip helps destroy harmful bacteria during drying, including *E. coli* O157:H7, *Salmonella* and *Listeria monocytogenes*. Several methods can be used.

Ascorbic Acid Treatment. Ascorbic acid (vitamin C) is an antioxidant that keeps fruit from darkening and enhances destruction of bacteria during drying. Pure crystals can be found at supermarkets and drug stores. Stir 2½ tablespoons (34 grams) of pure ascorbic acid crystals into one quart (~ 1 liter) of cold water. For small batches use 3¾ teaspoons (17 grams) of pure ascorbic acid crystals per 2 cups of cold water. Vitamin C tablets can be crushed and used (six 500 milligram tablets equal 1 teaspoon ascorbic acid). One quart of solution treats about 10 quarts of cut fruit. Cut peeled fruit into ascorbic acid solution. Soak for 10 minutes, remove with a slotted spoon, drain and dehydrate. Commercial antioxidant mixtures may be used, but are not as effective as ascorbic acid. Follow packaging instructions for fresh cut fruit.

Citric Acid or Lemon Juice Treatment. Citric acid or lemon juice may also be used as anti-darkening/antimicrobial treatments. Prepare the citric acid solution by stirring 1 teaspoon (5 grams) of citric acid into 1 quart (~ 1 liter) of cold water. For the lemon juice solution, mix equal parts of lemon juice and cold water (i.e., 1 cup lemon juice and 1 cup water). Cut the peeled fruit into the solution. Soak 10 minutes, remove with a slotted spoon, drain and dehydrate. Citric acid is often available in the canning section of supermarkets.

Sodium Metabisulfite Treatment. Sulfur and sulfite compounds have been used for centuries to prevent discoloration and spoilage during the preparation and storage of many foods. However, sulfites may initiate asthmatic reactions in some people, especially those with asthma. As a result, the Food and Drug Administration (FDA) has banned the use of sulfites on fresh produce served raw; however, they may be used in some dried fruits. Use U.S.P. (food grade) or Reagent Grade sodium metabisulfite, not Practical Grade. Sulfites can be found in pharmacies or where wine-making supplies are sold. Stir 1 tablespoon (21 grams) sodium metabisulfite into 1 quart (~ 1 liter) of cold water. Cut the peeled fruit into the sulfite

solution. Soak 10 minutes, remove with a slotted spoon, drain and dehydrate.

NOTE: Due to health and safety concerns, do not use burning sulfur to pre-treat dried fruits.

Cracking Skins. Grapes, prunes, small dark plums, cherries, figs and firm berries have tough skins with a wax-like coating. To better allow moisture to evaporate, crack or 'check' skins before drying whole fruits. To crack skins, dip fruit in boiling water for 30 to 60 seconds, then dip in very cold water. Drain on clean towels before drying.

Drying Fruits

Place pre-treated fruits on drying trays in single layers, pit cavity up. Dry at 140°F to 145°F (60° to 63°C) in a dehydrator or oven. The time needed to dry fruits depends on size, humidity and air circulation. Thinner slices and smaller pieces dry more quickly than larger, thicker pieces or whole fruits. Also, foods will generally dry more quickly in electric dehydrators or convection ovens than in conventional ovens. At 140°F, plan on about six hours for thin apple slices to 36 hours for peach halves. Stir food and turn large pieces every three to four hours during drying. Fruits scorch easily at the end of oven drying. Therefore, turn off the oven when drying is almost done and open the oven door for another hour.

Testing for Dryness

Dry foods enough to prevent microbial growth and spoilage. Dried fruits should be leathery and pliable. See Table 2 for dryness tests. To test foods for dryness, cool a few pieces to room temperature (warm fruits seem more moist and soft). Squeeze a handful of the fruit. If no moisture is left on the hand and pieces spring apart when released, they are dry.

Post-Drying Treatment

Conditioning. After drying, some pieces will be more moist than others due to their size and placement during drying. Conditioning evenly distributes moisture and reduces spoilage, especially from mold. To condition, place cooled, dried food loosely in large plastic or glass containers, about two-thirds full. Lightly cover and store in a warm, dry, well-ventilated place for four to 10 days. Stir or shake containers daily to separate pieces. If beads of moisture form, return food to drying trays for further drying, then repeat conditioning step.

Packaging and Storage

After conditioning, pack cooled, dried foods in small amounts in dry, scalded glass jars (preferably dark) or in moisture- and vapor-proof freezer containers, boxes or bags. Label and date packages. Store in a cool, dry, dark place, or in the refrigerator or freezer. Properly stored, dried fruits keep well for six to 12 months. Discard foods that have off odors or flavors, or show signs of mold.

Table 2. Steps for drying fruit

Fruit	Drying Procedure
Apples	Choose mature, firm apples. Wash well. Pare and core. Cut in rings or slices ⅛-¼ inch thick. Dip in ascorbic acid or other antidarkening/ antimicrobial solution for 10 minutes. Remove from solution; drain well. Arrange in single layer on trays. Dry until soft, pliable and leathery; no moist area in center when cut (6-12 hours).
Apricots	Select firm, fully ripe fruit. Wash well. Cut in half; remove pit. Do not peel. Dip in ascorbic acid or other antidarkening/ antimicrobial solution for 10 minutes. Remove from solution; drain. Place in single layer on trays, pit side up with cavity popped up to expose more flesh to the air. Dry until soft, pliable and leathery; no moist area in center when cut (24-36 hours).
Bananas	Choose firm, ripe fruit. Peel. Cut in ⅛ inch slices. Dip in ascorbic acid or other antidarkening/antimicrobial solution for 10 minutes. Remove and drain well. Arrange in single layer on trays. Dry until tough and leathery (6-10 hours).
Berries	Select firm, ripe fruit. Wash well. Leave whole or cut in half. For berries with firm skins (gooseberries) dip in boiling water 30 seconds to crack skins. For berries with soft skins (strawberries) dip in ascorbic acid or other antimicrobial solution for 10 minutes. Remove and drain well. Place on drying trays not more than two berries deep. Dry until hard and berries rattle when shaken on trays (24-36 hours).
Cherries	Choose fully ripe fruit. Wash well. Remove stems and pits. Dip whole cherries in boiling water 30 seconds to crack skins. May also dip in ascorbic acid or other antimicrobial solution for 10 minutes. Remove and drain. Place in single layer on trays. Dry until tough, leathery and slightly sticky (24-36 hours).
Citrus Peel	Select thick-skinned oranges without mold or decay and no color added to skin. Scrub oranges well with brush under cool running water. Thinly peel outer 1/16 to ⅛ inch of the peel; avoid white bitter part. Dip in ascorbic acid or other antimicrobial solution for 10 minutes. Remove from solution; drain well. Arrange in single layers on trays. Dry until crisp (8-12 hours).
Figs	Choose fully ripe fruit. Wash or clean well with damp towel. Peel if desired. Leave whole if small or partly dried on tree; cut large figs in halves or slices. If drying whole figs, crack skins by dipping in boiling water for 30 seconds. For cut figs, dip in ascorbic acid or other antimicrobial solution for 10 minutes. Remove and drain. Place in single layers on trays. Dry until leathery and pliable (12-24 hours).
Grapes and Black Currants	Select seedless varieties. Wash, sort, remove stems. Cut in half or leave whole. If drying whole, crack skins by dipping in boiling water for 30 seconds. If halved, dip in ascorbic acid or other antimicrobial solution for 10 minutes. Drain. Dry until pliable and leathery with no moisture in center (12-24 hours).
Melons	Choose mature, firm fruits that are heavy for their size (cantaloupe dries better than watermelon). Scrub outer surface well with brush under cool running water. Remove outer skin, fibrous tissue and seeds. Cut into ¼ to ½ inch thick slices. Dip in ascorbic acid or other antimicrobial solution for 10 minutes. Remove and drain. Place on trays in single layer. Dry until leathery and pliable with no pockets of moisture (6-10 hours).

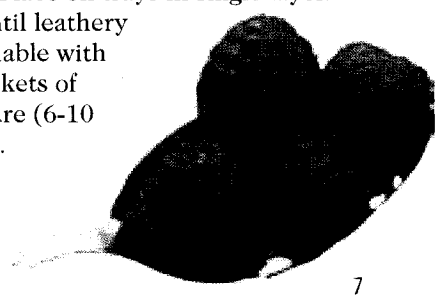


Table 2. Steps for drying fruit, continued

Fruit	Drying Procedure
Nectarines and Peaches	Select ripe, firm fruit. Wash and peel. Cut in half and remove pit. Cut in quarters or slices if desired. Dip in ascorbic acid or other antidarkening/ antimicrobial solution for 10 minutes. Drain. Place on trays pit side up in single layer. Turn halves over when visible juice disappears. Dry until leathery and pliable (6-10 hours for slices or 24-36 hours for halves).
Pears	Choose ripe, firm fruit. Bartlett variety is recommended. Wash well. Pare if desired. Cut in half lengthwise and core. Cut in quarters, eighths or slices ⅛ to ¼ inch thick. Dip in ascorbic acid or other antidarkening/ antimicrobial solution for 10 minutes. Remove and drain. Arrange in single layer on trays pit side up. Dry until springy and suede-like with no pockets of moisture (6-10 hours for slices or 24-36 hours for halves).
Plums and Prunes	Wash well. Leave whole if small; cut large fruit into halves (pit removed) or slices. If left whole, crack skins in boiling water 1-2 minutes. If cut in half, dip in ascorbic acid or other antimicrobial solution for 10 minutes. Remove and drain well. Arrange in single layer on trays pit side up, cavity popped out. Dry until pliable and leathery (6-10 hours for slices or 24-36 hours for halves).
Tomatoes	Dip in boiling water to loosen skins. Chill in cold water. Peel. Slice ½ inch thick or cut in ¾ inch sections. Dip in ascorbic acid or other antimicrobial solution for 10 minutes. Drain. Place on trays in single layer. Dry until crisp (6-10 hours for slices or 24-36 hours for halves).

Using Dried Fruits

To cook dried fruit, cover with boiling water and simmer covered until tender (about 15 minutes). If needed, sweeten to taste near the end of cooking or after removing from heat. Most dried fruits need no extra sweetening. If desired, add a few grains of salt to help bring out the fruit's natural sweetness, or add a little lemon, orange or grapefruit juice just before serving to add flavor and vitamin C.

To reconstitute fruit for use in a cooked dish, such as a pie, place it in a bowl and cover with boiling water. Soak until tender and liquid is absorbed (one hour or longer). Thinly sliced fruits may not require soaking before using in cooked dishes.

Reconstituted or dried fruits are excellent in cobblers, breads, pies, puddings, gelatin salads, milk shakes and cooked cereals. Any remaining liquid, after soaking, can be used as part of the water needed in the recipe.

Drying Fruit Leathers

Fruit Leather

- Fruit leather is made by drying thin layers of pureed fruit in a dehydrator or oven. Fruit leather is easy to prepare and a good way to use left-over canned fruit and slightly over-ripe fresh fruit.
- Also called fruit rolls or taffies, fruit leathers make wholesome and nutritious snacks for backpackers, campers and active children.
- Fruit leathers can be eaten as is, or made into a beverage (combine 5 parts water with 1 part leather in a blender). They also can be used in pie fillings, in cooking and as a dessert topping.

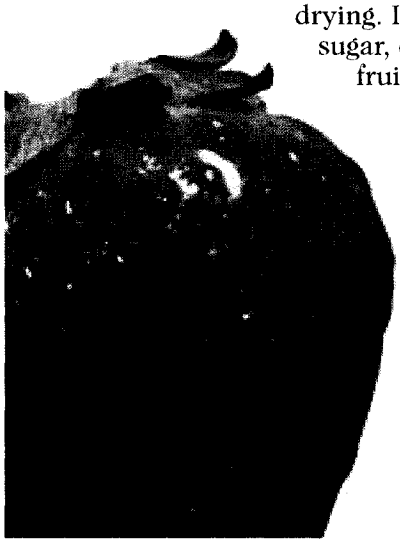
Apples, apricots, bananas, berries, grapes, melons, oranges, peaches, pears, pineapples, plums, and most tropical fruits can be blended and dried to make fruit leathers. Do not use grapefruit and lemons because they turn bitter when dried.

Fruit Leather Preparation

Select and Prepare Fruit. Select ripe or slightly over-ripe fruit. Sort and thoroughly rinse or scrub the fruit under running water. Remove and discard blemishes or defects. Peel tough-skinned fruits such as winter apples, oranges, peaches and pears. Pit and core as needed. Remove seeds from grapes and hull strawberries.

Cook fruit. Cut fruit into chunks and cook in steam or the microwave oven until soft. To steam heat, place in the top of a double boiler. Add water to the bottom of the double boiler and bring to a boil. Cover and steam 15 to 20 minutes or until fruit is soft and a thermometer placed in the mixture registers 160°F. To microwave cook, place cut fruit in a glass casserole dish. Cover and microwave on full power (high) for 6 to 8 minutes per two cups of fruit, stirring every 2 minutes.

Prepare fruit puree. Place cooked fruit in a blender. Add ½ teaspoon of ascorbic acid crystals or 2 tablespoons lemon juice per two cups of fruit to protect the color and help destroy bacteria during drying. If desired, add 1 to 2 tablespoons sugar, corn syrup or honey per two cups fruit and a small amount of spice (¼ teaspoon cinnamon or a dash of nutmeg per two cups puree) for taste. Blend until smooth.



Shortcut Canned Method. Substitute canned fruit or strained baby food without tapioca for the cooked fruit above. Canned applesauce and strained baby fruit need not be pureed. Drain other canned fruits and puree in a blender, food grinder or by hand.

Canned fruits are already processed, which destroys bacteria

and stops enzyme action. Thus, the addition of ascorbic acid or lemon juice is not necessary. Canned fruits, such as applesauce, can be mixed with more expensive fresh fruits to help stretch the fruit concentrate and soften the flavor of sharp-tasting fruits, such as cranberries. Adding applesauce to juicy fruits eases drying.

Drying Fruit Leather

Spray a cookie sheet or flat tray with cooking spray or line with plastic wrap. Make sure the tray has an edge to prevent spillage of the puree. Spread the fruit concentrate evenly over the pan surface to a depth of ⅛ to ¼-inch. Two cups of puree is enough to cover a 12- by 17-inch cookie sheet. Dry in a dehydrator or oven.

Dehydrator Drying. Place sheets or trays of fruit concentrate in the dehydrator. Set temperature at 140°F to 145°F. Test frequently for dryness. The puree should be dry in four to 10 hours, depending on thickness and air humidity.

Oven Drying. Set oven on lowest setting (140° to 145°F). Place trays of puree on the oven rack and leave the door open 2 to 6 inches. Check the oven temperature with a thermometer every 1 to 2 hours to be sure it's at 140° to 145°F.

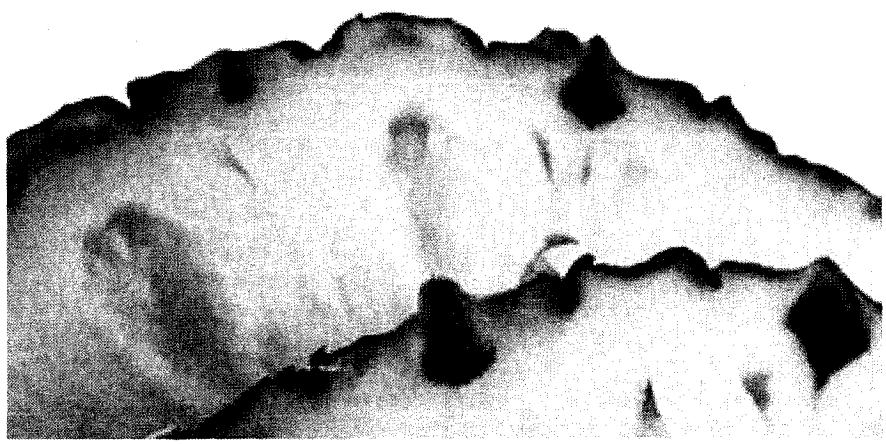
If needed, turn off the oven for a short time to reduce the temperature. The fruit concentrate should dry in four to 10 hours. Test often for dryness.

Testing for Dryness

Properly dried fruit leather will be somewhat clear and tacky, but easily peeled from the pan or plastic wrap. Test for dryness by touching the leather in several places; no indentations should be left. Lift the edge of the leather, which will stick tightly to the surface, and peel it back about an inch. If it peels easily, it is dry. If the leather has cooled, it may need to be warmed for a few minutes to help it peel more easily. If the leather cracks or chips, it has dried for too long, but is still edible.

Packaging and Storage

After loosening the edge of the leather from the plastic wrap or pan, loosely roll the leather in plastic wrap or waxed paper. Store the roll in one piece or cut into 1-inch strips. Place the strips or rolls in a plastic bag, glass container, paper bag or other container. Until



the leather is completely dry, do not tighten the container lid or tightly twist the bag opening. If the leather is not completely dry, it may become sticky or develop mold growth during storage. Discard leathers that have off odors or flavors, or show signs of mold.

Store fruit leather in a cool, dry, dark place. Leathers will retain good quality for up to one year in the freezer, several months in the refrigerator, or one to two months at room temperature (70°F). Nutrients become concentrated in dried fruit, and so do calories. A 1- by 17-inch strip of applesauce leather provides about 40 calories, if two cups of canned sweetened applesauce were dried on a 12- by 17-inch pan.

Drying Vegetables

The following vegetable drying methods were developed as part of a research project between the departments of food science and human nutrition and animal sciences at Colorado State University, and were found to effectively reduce pathogen populations on inoculated samples.

Selecting Vegetables

Choose vegetables at peak flavor and eating quality (just as they reach maturity). Sweet corn and green peas should be slightly immature so they retain their sweet flavor. Refer to Table 3 for fresh-to-dried ratios for a variety of vegetables.

Picking activates enzymes that cause color, flavor, texture, sugar content and nutrient changes. To control such changes, prepare and process vegetables at once. Thoroughly wash or clean to remove surface dirt, bacteria or residues. Drain. Shake leafy vegetables well. Sort and discard food with decay, bruises or mold. Such defects may affect all pieces being dried. Follow preparation steps in Table 4.

Table 3. Yield of dried vegetables

	Amount picked or purchased	Amount dried product	
Produce	**Pounds**	**Pounds**	**Pints**
Beans, lima	7	1¼	2
Beans, snap	6	½	2½
Beets	15	1½	3 to 5
Broccoli	12	1⅜	3 to 5
Carrots	15	1¼	2 to 4
Celery	12	¾	3½ to 4
Corn	18	2½	4 to 4½
Greens	3	¼	5½
Onions	12	1½	4½
Peas	8	¾	1
Pumpkin	11	¾	3½
Squash	10	¾	5

Source: Drying Foods at Home, Marjorie M. Philip. Cooperative Extension Service. University of Arkansas, Little Rock, Arkansas 72203.

Treating Vegetables for Quality and Safety

Treat vegetables by blanching in boiling water or citric acid solution (see Table 4). This slows or stops the enzyme activity that causes undesirable changes in flavor and texture during storage. Blanching also speeds drying and helps protect vitamins and color. Research shows that blanching vegetables in water or a citric acid solution helps destroy harmful bacteria during drying, including *E. coli* O157:H7, *Salmonella* and *Listeria monocytogenes*.

Blanching. Water blanching is recommended over steam or microwave blanching because water blanching heats the food more evenly than the other two methods. Plain water or water with added citric acid may be used. Citric acid acts as an anti-darkening and anti-microbial agent. Prepare the citric acid water by stirring ¼ teaspoon (1 gram) citric acid into 1 quart (~1 liter) water. Work with small amounts so the plain or citric acid water doesn't stop boiling. Watch closely and pre-cook as follows:

- Fill large kettle half full with plain water or citric acid water and bring to a boil.
- Put no more than 1 quart of the vegetable pieces in a cheese cloth or mesh bag. A 36-inch cloth square gathered at the corners works well. Secure ends.
- Place bag in boiling water. Be sure all pieces are immersed.
- Start timing as soon as vegetables are in boiling water or citric acid solution. Adjust heat for continuous boiling.
- Heat for length of time shown in Table 4.
- Place bag in cold water to cool (same amount of time as blanched).
- Drain on paper towel or cloth.

Drying Vegetables

Place blanched vegetables on drying trays in a thin layer, ½ inch deep or less. Dry at 140°F to 145°F (60° to 63°C) in a dehydrator or oven. The time needed to dry vegetables depends on the size of the pieces, humidity and air circulation. Thinner slices and smaller pieces dry more quickly than larger, thicker pieces or whole vegetables. Food generally will dry more quickly in electric dehydrators or convection ovens than in conventional ovens. At 140°F, plan on about six hours for thin carrot slices to 24 hours for whole chili peppers (see Table 4).

Stir food, turn large pieces of food and shift trays every three to four hours during drying. Vegetables may scorch toward the end of oven drying. Therefore, it's best to turn off the power when drying is almost complete and open the oven door for another hour before removing pieces.

Drying Herbs

See Table 4 for information on drying herbs.

Testing for Dryness

Foods should be dry enough to stop microbial growth and spoilage. Dried vegetables should be hard and brittle. Remove a small handful of food and let cool a few minutes before testing for dryness (warm foods seem more moist than they really are). See Table 4 for dryness tests.

Post-Drying Treatment

Conditioning. When drying is complete, some pieces will be more moist than others due to size and location during drying. Conditioning distributes moisture evenly in dried food and reduces spoiling. Because vegetables are dried to a near-waterless state, the conditioning step may not be necessary. (See *Conditioning* section for how to condition dried vegetables.)

Packaging and Storing

Pack cooled, dried foods in small amounts in dry, scalded glass jars (preferable dark) or in moisture- and vapor-proof freezer containers, boxes or bags. Metal cans may be used if food is first placed in a freezer bag. To keep out insects and moisture, seal lids onto containers. Wrap the edge where the lid meets the container with a plasticized, pressure-sensitive tape or clean, 1-inch cloth strip dipped in melted paraffin. Bags may be heat-sealed or closed with twist ties, string or rubber bands. Supplies are often available in the canning section of supermarkets.

Label containers with the name of the food, date, and method of treatment and drying. Store in cool, dry, dark place. Properly stored, dried vegetables keep well for six to 12 months. Discard food if off odors or flavors develop, or you see signs of mold.

Using Dried Vegetables

One cup of dried vegetables reconstitutes to about two cups. To rehydrate and cook leafy or tender vegetables (cabbage, chard, kale, spinach), cover with hot water and simmer to desired tenderness. Soak root, stem and seed vegetables (carrots, corn, green beans, peas) before cooking. Cover with cold water and soak ½ to 1½ hours, or cover with boiling water and soak 20 to 60 minutes. After soaking, simmer until tender.

Dehydrated vegetables have a unique texture and flavor. They are best used in soups, casseroles, sauces, stuffings and stews.

Table 4. Steps for drying vegetables (See text for details)

Vegetable	Preparation	Blanching Time* (mins)	Drying Time** (hours)	Dryness Test
Asparagus	Wash thoroughly. Halve large tips.	4-5	6-10	Leathery to brittle
Beans, green	Wash. Cut in pieces or strips.	4	8-14	Very dry, brittle
Beets	Cook as usual. Cool, peel. Cut into shoestring strips ⅛ inch thick.	None	10-12	Brittle, dark red
Broccoli	Wash, trim. Cut as for serving. Quarter stalks lengthwise.	4	12-15	Crisp, brittle
Brussels sprouts	Wash. Cut in half lengthwise through stem.	5-6	12-18	Tough to brittle
Cabbage	Wash. Remove outer leaves, quarter and core. Cut into strips ⅛ inch thick.	4	10-12	Crisp, brittle
Carrots; Parsnips	Use only crisp, tender vegetables. Wash. Cut off roots and tops; peel. Cut into discs or strips ⅛ inch thick.	4	6-10	Tough to brittle
Cauliflower	Wash, trim. Cut into small pieces.	4-5	12-15	Tough to brittle
Celery	Trim stalks. Wash stalks and leaves thoroughly. Slice stalks.	4	10-16	Very brittle
Chili peppers, green	Wash. To loosen skins, cut slit in skin, then rotate over flame 6-8 minutes or scald in boiling water. Peel and split pods. Remove seeds and stem. (Wear gloves if necessary.)	None	12-24	Crisp, brittle, medium green
Chile peppers, red	Wash thoroughly. Slice or leave whole if small.	4	12-24	Shrunken, dark red pods, flexible
Corn, cut	Husk, trim. Wash well. Blanch until milk in corn is set. Cut kernels from the cob.	4-6	6-10	Crisp, brittle
Eggplant	Wash, trim, cut into ¼ inch slices.	4	12-14	Leathery to brittle
Horseradish	Wash, remove small rootlets and stubs. Peel or scrape roots. Grate.	None	6-10	Brittle, powdery
Herbs (basil, cilantro, parsley, etc.)	Wash thoroughly. Separate clusters. Discard long or tough stems. Dip in solution of 1 tsp. citric acid per quart water for 10 minutes. Drain.	None	4-6	Flaky
Mushrooms***	Scrub. Discard tough, woody stalks. Slice tender stalks ¼ inch thick. Peel large mushrooms, slice. Leave small mushrooms whole. Dip in solution of 1 tsp. citric acid/quart water 10 minutes. Drain.	None	8-12	Dry and leathery
Okra	Wash thoroughly. Cut into ½ inch pieces or split lengthwise.	4	8-10	Tough, brittle
Onions	Wash, remove outer paper skin. Remove tops and root ends, slice ⅛-¼ inch thick.	4	6-10	Very brittle
Parsley	See Herbs	None	4-6	Brittle

Peas	Shell and wash.	4	8-10	Hard, wrinkled, green
Peppers; Pimentos	Wash, stem. Remove core and seeds. Cut into ¼-½ inch strips or rings.	4	8-12	Tough to brittle
Potatoes	Wash, peel. Cut into ¼ inch shoestring strips or ⅛ inch thick slices.	7	6-10	Brittle
Spinach; greens like Kale, Chard, Mustard	Trim and wash very thoroughly. Shake or pat dry to remove excess moisture.	4	6-10	Crisp
Squash, Summer or Banana	Wash, trim, cut into ¼ inch slices.	4	10-16	Leathery to brittle
Squash, Winter	Cut into pieces. Remove seeds and cavity pulp. Cut into 1 inch wide strips. Peel rind. Cut strips crosswise into pieces about ⅛ inch thick.	4	10-16	Tough to brittle
Tomatoes	See Drying Fruits			

* Blanching times are for 3,000 to 5,000 feet. Times will be slightly shorter for lower altitudes and slightly longer for higher altitudes or for large quantities of vegetables.

** Dry in thin layers on trays to recommended state of dryness.

*** WARNING: Toxins of poisonous varieties of mushrooms are not destroyed by drying or cooking. Only an expert can differentiate between poisonous and edible mushroom varieties

Drying Jerkies

Meat Jerky Safety

The following jerky preparation methods were developed and evaluated as part of a research project between the departments of food science and animal sciences at Colorado State University, and effectively reduced microbial populations on inoculated samples.

Jerky Preparation

Use only lean meats in excellent condition. Round, flank, chuck steak, rump roast, brisket and cross rib are good choices. Marbled and fatty cuts do not work well. When preparing jerky, keep raw meats and their juices away from other foods. Remove thick connective tissue and gristle from meat. Remove visible fat with a sharp knife (fat turns rancid and causes off-flavors in jerky). Freeze meat in moisture-proof paper or plastic wrap until firm (not solid).

Slice meat on a clean cutting board while still slightly frozen into long thin strips, about ⅛ to ¼ inch thick, 1 to 1½ inches wide and 4 to 10 inches long. For chewy jerky, slice with the grain; slice across the grain for tender, brittle jerky. Lay the strips out in a single layer on a clean and sanitized cutting board, counter top or cookie sheet. Flatten strips with a rolling pin so they are about the same thickness.

Note: Always wash and sanitize cutting boards, utensils, and counter tops with hot, soapy water before and after contacting

raw meat or juices. To make a sanitizing solution, use 1 teaspoon of household chlorine bleach per 1 quart of water.

I. Hot Pickle Cure Preparation Method

Ingredients per two pounds of lean meat slices

Pickling Spices:
1½ tablespoons salt
1 tablespoon sugar
1 teaspoon black pepper

Hot Pickle Brine:
¾ cup salt
½ cup sugar
2 tablespoons black pepper
1 gallon water

Directions: Place jerky slices on clean cookie sheets or flat pans. Sprinkle half of the pickling spices on the top surfaces of meat slices. Press spices into the meat with a rubber mallet or meat tenderizer. Turn slices and repeat on opposite side. Cover and refrigerate for 24 hours.

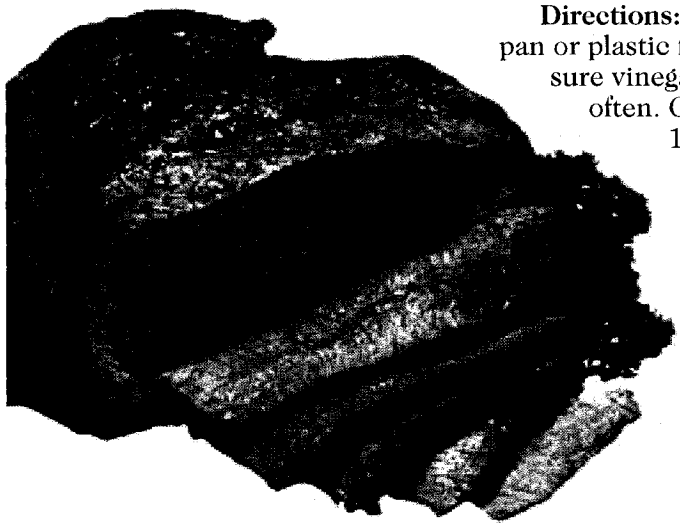
Combine ingredients for hot pickle brine (salt, sugar, pepper, water) in a large kettle. Stir to dissolve salt and sugar and bring to a slow boil (175°F). Place a few meat slices at a time in a steamer basket and lower into brine. Simmer for 1½ to 2 minutes; stir often to make sure all pieces are immersed.

Lift basket out of kettle and drain. Using clean tongs, remove meat pieces and place flat, without touching each other, on clean dehydrator trays, oven racks or other drying trays. Repeat process until all meat pieces have been pickled in the brine and placed on trays. See *Jerky Drying* section for drying instructions.

II. Vinegar-Marinade Preparation Method

Ingredients per two pounds of lean meat slices

Pre-treatment Dip:
2 cups vinegar
Marinade ingredients:
¼ cup soy sauce
1 tablespoon Worcestershire sauce
¼ teaspoon black pepper
¼ teaspoon garlic powder
½ teaspoon onion powder
1 teaspoon hickory smoked salt



Directions: Place two cups vinegar in 9 x 11-inch glass cake pan or plastic food storage container. Add meat strips, making sure vinegar covers all strips. Soak 10 minutes, stirring often. Combine marinade ingredients and place in a 1-gallon re-sealable plastic bag. Add meat slices to bag; seal and massage pieces to distribute marinade over all meat strips. Refrigerate bag one to 24 hours.

Using clean tongs, place meat strips in single layers, flat and without touching each other, on clean drying trays or oven racks and dry as directed below.

Jerky Drying

Use a calibrated thermometer to monitor circulating air temperature of the dehydrator or oven. Pre-heat to 140° to 145°F for 15 to 30 minutes. Place the filled trays in pre-heated dehydrator or oven, leaving open space on the racks for air to circulate around the strips. Let dry at 140° to 145°F for 10 to 14 hours, or until pieces are dry.

Testing for Dryness

Properly dried jerky is chewy and leathery. It will be as brittle as a green stick, but won't snap like a dry stick. To test for dryness, remove a strip from the dehydrator or oven. Let cool slightly and bend; the jerky should crack but not break. When dry, remove jerky strips from the drying trays to a clean surface. Pat off beads of oil with a paper towel and cool.

Post-Drying Treatment

Conditioning. When drying is complete, some pieces will be more moist than others. Conditioning distributes moisture evenly in dried food and reduces spoiling. See *Conditioning* section on page 6 for how to condition jerky

Packaging and Storing

After conditioning, place cooled jerky strips in an airtight plastic food bag or jar with a tight fitting lid. Pack jerky with the least possible amount of air in the container. Too much air causes off-flavors and rancidity. Label and date packages.

Store containers of jerky in a cool, dry, dark place, or the refrigerator or freezer. Properly dried jerky can be stored for one to two months in a sealed container at room temperature. It will keep for up to six months in the refrigerator and one year in the freezer. Check often for mold. Discard food that develops off odors, flavors or mold.

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Drying Foods Bulletin

Materials Rating Form

I.D.#: **First two letters of mother's first name ___ Last two numbers of the year of your birth ___**

What is your reaction to the *Drying Foods* bulletin you have just reviewed? Please circle the number next to each phrase that represents your rating of the bulletin.

Is this information:

Easy to understand?	1 Not very easy to understand	2	3	4	5	6	7 Very easy to understand
Useful to you?	1 Not very useful	2	3	4	5	6	7 Very useful
Believable?	1 Not very believable	2	3	4	5	6	7 Very believable
Difficult to read?	1 Not very difficult difficult to read	2	3	4	5	6	7 Very difficult to read
Eye-catching?	1 Not very eye-catching	2	3	4	5	6	7 Very eye-catching
Are the graphics appropriate?	1 Not very appropriate	2	3	4	5	6	7 Very appropriate
Would you be willing to follow the recommendations given in the bulletin?	1 Not very willing	2	3	4	5	6	7 Very willing
Overall, do you like this bulletin?	1 Dislike extremely	2	3	4	5	6	7 Like extremely
Would you recommend this bulletin to a friend who dehydrates foods?	1 Would not highly recommend	2	3	4	5	6	7 Would highly recommend

Comments:

Figure A7.4. Materials rating form.

Table A7.1. Respondents (n= 55) mean (standard deviation) rating scores for *Drying Foods* bulletin. Values are based on a seven-point hedonic scale.

Question	Mean (SD)
1. Easy to understand? [a]	6.2 (0.9)
2. Useful to you? [b]	6.4 (1.2)
3. Believable? [c]	6.3 (1.0)
4. Difficult to read? [d]	2.0 (1.5)
5. Eye-catching? [e]	5.7 (1.3)
6. Are the graphics appropriate? [f]	5.7 (1.4)
7. Would you be willing to follow the recommendations given in the bulletin? [g]	6.7 (0.7)
8. Overall, do you like this bulletin? [h]	6.3 (0.9)
9. Would you recommend this bulletin to a friend who dehydrates foods? [i]	6.8 (0.5)

[a] (1 = "not very easy to understand"; 7 = very easy to understand")
[b] (1 = "not very useful"; 7 = very useful")
[c] (1 = "not very believable"; 7 = very believable")
[d] (1 = "not very difficult to read"; 7 = very) difficult to read"). A low score is desired for this item.
[e] (1 = "not very eye-catching"; 7 = very eye-catching")
[f] (1 = "not very appropriate"; 7 = very appropriate")
[g] (1 = "not very willing"; 7 = very willing")
[h] (1 = "dislike extremely"; 7 = like extremely")
[i] (1 = "would not highly recommend"; 7 = would highly recommend")

Dried Vegetable Sensory Evaluation

Consumer #: _____

1. Please circle the appropriate responses to the following questions.

Gender: Male Female
Status: Faculty Staff Student Other
Age: Under 21 years old 21 to 34 years old Over 34 years old
Have you ever dried carrots/potatoes at home? Yes No
Do you like to eat dried vegetables? Yes No
(homemade potato chips and/or reconstituted in a soup/stew mix)

How often do you eat dried vegetables? 1x /week or more 1-3 x /month 1-6 x /year Never
(homemade potato chips and/or reconstituted in a soup/stew mix)

How often do you purchase dried vegetables? 1x /week or more 1-3 x /month 1-6 x /year Never
(dehydrated, potato chips and/or as part of a soup/stew mix)

2. Score each sample for the attributes listed below by circling the number that represents your rating of the sample. Please cleanse palate with crackers and water between tasting samples.

	Sample:								
Appearance:	1 Dislike Extremely	2	3	4	5 Neither Dislike nor Like	6	7	8	9 Like Extremely
Flavor Description:	1 Dislike Extremely	2	3	4	5 Neither Dislike nor Like	6	7	8	9 Like Extremely
Flavor Acceptability:	1 Dislike Extremely	2	3	4	5 Neither Dislike nor Like	6	7	8	9 Like Extremely
Color:	1 Extremely Light	2	3	4	5 Neither Light nor Dark	6	7	8	9 Extremely Dark
Texture:	1 Extremely Brittle/Hard	2	3	4	5 Neither Brittle nor Soft	6	7	8	9 Extremely Soft
Overall Acceptability:	1 Dislike Extremely	2	3	4	5 Neither Dislike nor Like	6	7	8	9 Like Extremely

Comments:

Figure A7.5. Sensory evaluation form for dehydrated vegetable slices.

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September 29, 2004

Dear Workshop participant:

Approximately six weeks ago you attended a Food Safety and Food Drying Workshop presented by Dr. Pat Kendall and/or myself. We hope you gained useful information from the dried foods research being conducted here at Colorado State University.

Your involvement in the workshop has been invaluable to us and we greatly appreciated your participation. Because of your input, we have the knowledge and ability to improve future educational materials and workshops.

Currently we are in the final stages of our research project and need your help. Please take a moment to complete the enclosed survey and return it to us using the self addressed, stamped envelope provided.

Thank you so much for your time and cooperation in this important research project.

Sincerely,

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Follow up Workshop Survey

Date:_____ **Workshop Location:**_____

ID: First two letters of mother's name __ __ Last two numbers of birth year ___ ___

Please check whether you agree or disagree with the following statements:

Agree Disagree

___A ___D Foodborne illness outbreaks have been associated with beef jerky and venison jerky.
___A ___D I don't think it's important to monitor oven temperature throughout food food drying.
___A ___D I don't think it's important to monitor dehydrator temperature throughout food drying.
___A ___D I don't worry that jerky may be contaminated with microorganisms and make me sick.
___A ___D I don't worry that dried fruits and vegetables may be contaminated with microorganisms and make me sick.
___A ___D Microorganisms are not able to grow or survive on dried fruits and vegetables.
___A ___D In the past 15 years, the number of produce-associated foodborne illness outbreaks per year has decreased.
___A ___D I am not concerned about case-hardening of meats during drying.
___A ___D I am not concerned about case-hardening of fruits and vegetables during drying.
___A ___D To maintain the best flavor and quality, store jerky in the refrigerator or freezer.
___A ___D Dipping fruits in a solution containing ascorbic acid (Vitamin C), citric acid, or lemon juice may help enhance the destruction of microorganisms during drying.
___A ___D Steam blanching vegetables before drying effectively enhances destruction of microoganisms.
___A ___D Water blanching vegetables before drying effectively enhances destruction of microorganisms.
___A ___D Sun/solar drying is a safe way to dry meats.
___A ___D Sun/solar drying is a safe way to dry fruits and vegetables.

___A ___D I don't think it's important to store dried meats (jerky) in airtight containers.
___A ___D I don't think it's important to store dried produce in airtight containers.

___A ___D I think it is better to dry foods in a food dehydrator than in the oven.
___A ___D I think it is important to condition dried meat before packing for storage.

___A ___D Dried fruits and vegetables should never be conditioned before storage.

We are interested in your food drying practices *before* attending our presentation, and changes you may have made *as a result of the presentation.*

	Extremely Unsafe		**Somewhat Safe**		**Extremely Safe**	
1. ***Before*** attending the presentation, I would *now* rate my food drying practices as:	1	2	3	4	5	
2. As a ***direct result*** of attending the presentation, I would *now* rate my food drying practices as:	1	2	3	4	5	
	I don't usually do this		**I Sometimes do this**		**I have always done this**	
2. Thermometer use: A) I use a thermometer to monitor dehydrator temperature during drying:	1	2	3	4	5	NA
B) I use a thermometer to monitor oven temperature during drying:	1	2	3	4	5	NA

3. Do you dry meat slices? ____ NO ____ YES

*If you do **not** dry meat slices, skip to question **4.** If you dry meat slices, once they are prepared, do you do any of the following before drying:*

	I don't usually do this		**I Sometimes do this**		**I have always done this**
A) I do nothing:	1	2	3	4	5
B) I cook meat slices to 160°F:	1	2	3	4	5
C) I treat meat slices with pickling spices, then a hot pickling brine:	1	2	3	4	5
D) I marinade the meat slices:	1	2	3	4	5
E) I dip meat slices in vinegar, then marinade:	1	2	3	4	5

4. Do you dry fruits such as apple and peach slices/pieces? ____ NO ____ YES

*If you do **not** dry fruits such as apple and peach slices/pieces,skip to question 5*

If you do dry fruits such as apple and peach slices/pieces, once they are prepared, do you do any of the following before drying:

	I don't usually do this		**I Sometimes do this**		**I have always done this**
A) I do nothing:	1	2	3	4	5
B) I dip the fruit in a solution of half lemon juice/half water:	1	2	3	4	5
C) I dip the fruit in a citric acid solution:	1	2	3	4	5
D) I dip the fruit in an ascorbic acid/Vitamin C solution:	1	2	3	4	5
E) I dip fruit in a sulfite solution:	1	2	3	4	5

5. Do you dry vegetables such as carrot slices? ____ NO ____ YES

*If you do **not** dry vegetables such as carrot slices,skip to question 6*

If you do dry vegetables such as carrot slices, once they areprepared, do you do any of the following before drying:

	I don't usually do this		**I Sometimes do this**		**I have always done this**
A) I do nothing:	1	2	3	4	5
B) I steam blanch the slices:	1	2	3	4	5
C) I water blanch the slices:	1	2	3	4	5
D) I water blanch the slices in a citric acid solution:	1	2	3	4	5

Demographic Information:

6. Are you (*check all that apply):*

____ of Hispanic Origin (Mexican, Hispanic, Latino) ____ White, Caucasian

____ Asian or Pacific Islander ____ Mixed Race, Other

____ Black, African American

7. What is your age? ____ Years

8. Are you: ____ Female ____ Male

9. Please identify your affiliations/occupations (*check all that apply*):

____ Master Food Preserver ____ Consumer

____ 4H Leader/Volunteer ____ Other:_____

____ Cooperative Extension Agent

10. Did you dry foods in the last year? ____ Yes ____ No ____ Not Sure

If Yes, check which types: ____ Meats ____ Fruits/Leathers

____ Vegetables ____ Herbs ____ Other_____

11. Did you dry foods in the last **5** years?____ Yes ____ No ____ Not Sure

If Yes, check which types: ____ Meats ____ Fruits/Leathers

____ Vegetables ____ Herbs ____ Other_____

Figure A7.6. Follow up Workshop survey.

Table A7.2. Mean[1] (SD) pH and water activity of carrot slices and potato slices following various treatments [Control (untreated), blanched in 0.105% citric acid (88°C, 4 min), or blanched in 0.21% citric acid (88°C, 4 min)] and dehydration for 6 h at 60°C (140°F).

	Control[2]		0.105% Citric Acid Blanched[3]		0.21% Citric Acid Blanched[4]	
	pH	aw	pH	aw	pH	aw
Carrot Slices	5.44A (0.22)	0.328a (0.028)	4.31B (0.06)	0.342a (0.029)	3.90B (0.09)	0.325a (0.015)
Potato Slices	5.63A (0.19)	0.143a (0.021)	5.18B (0.39)	0.138a (0.011)	5.04B (0.67)	0.144a (0.021)

[1] Means represent six values (n=6) (LSD=0.60).
[2] Control (no treatment), blanched in 0.105% citric acid [3] (88°C, 4 min), or blanched in 0.21% citric acid [4] (88°C, 4 min).
A-B means with different letters within a row are significantly different (P<0.05).
a-b means with different letters within a row are significantly different (P<0.05).