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Development of a novel economical device to improve post-harvest processing practices on small farms

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ABSTRACT

Consumer demand for fresh produce has increased; however, multiple microbial foodborne outbreaks in the past decade have involved fresh leafy greens. While large farms may process their own leafy greens or use an external processor that uses aqueous sanitizers, small farms may not have these options. Hence, it is important to equip small farmers with simple and effective methods to reduce on-farm pathogen contamination. The goal of this study was to develop a novel device that can improve post-harvest practices on small farms growing leafy greens. A survey was administered to identify farmers' concerns associated with the post-harvest phase of production. The results indicated that most farmers do not wash leafy greens in a sanitizing solution, but would like information on how to improve the safety of their produce. As a result of this survey, a novel sanitizing device was developed to wash, sanitize (with diluted white vinegar containing acetic acid (AA)), and dry leafy greens. The result showed that 1.6% AA for 2 min was effective against coliforms, yeast, mold, and pathogenic surrogates (*Listeria*, *Salmonella*, and *Escherichia coli*). Significant reduction of aerobic bacteria and coliforms were observed at 2.5% AA for 2 min and 1.6% for 2 min treatment at 3 log CFU/g and 2.28 log CFU/g respectively. The use of this device may help farmers wash and sanitize fresh leafy greens effectively, reduce the risk of foodborne pathogen contamination, and improve produce shelf-life.

1. Introduction

An increase in consumption of fresh produce followed by a strong consumer movement toward supporting local or regional food markets and purchasing directly from the producer (farmers' markets or Community Supported Agriculture programs) has been observed in recent years (Martinez et al., 2010). According to the most recent National Organic Farmers' Survey by the Organic Farming Research Foundation (OFRF, 2004) 80% of respondents who produced vegetables, herbs, floriculture, mushrooms, and/or honey products sold them through consumer-direct channels which include the following: direct on-farm sales, farmers markets, CSA or subscription, and mail order.

As produce consumption has increased, the Centers for Disease Control and Prevention (CDC) reported another significant trend; an increase in foodborne illnesses associated with produce (CDC, 2012). Foodborne illness outbreaks are of major concern to the public as the symptoms can range from gastroenteritis to death. Several outbreaks of gastroenteritis in humans have been associated with the consumption of fresh produce (Beuchat, 1996). Pathogenic *Escherichia coli* and *Salmonella* are commonly found in a wide variety of food items including raw meats, dairy products, fruits and vegetables, and water (Lang, Harris, & Beuchat, 2004). Pathogenic *E. coli* and *Salmonella* contamination may occur on farms through the use of contaminated irrigation water and manure (Bopp et al., 2003). The Good Agricultural Practices (GAP) manual provided by the U. S. Food and Drug Administration (FDA) states that microbiological contamination may also occur during the harvesting. Contamination may be introduced by farm workers, soil, harvest equipment (such as knives or clippers), field containers or harvest-aid surfaces, or from transport vehicles (Islam et al., 2004). Contamination vectors may come in contact with fresh produce and lead to foodborne disease outbreaks if effective post-harvest processing interventions (such as washing and sanitizing fresh produce) are not employed (Neal et al., 2011). However, in some cases, the bacteria may be internalized into the vascular system of the plant and post-harvest interventions may not be effective (Erickson et al., 2010).

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1.1. Natural antimicrobial sanitizers

Currently, chlorine is the sanitizing agent most used by the produce industry mainly due to its antimicrobial activity and low cost (Scharff, 2010). However, public health concerns have increased due to the possible formation of chlorinated organic compounds and their postulated persistence as an environmental toxin (Hobson, 1969). In addition, the emergence of new and more tolerant pathogens has raised doubts about the use of chlorine by the produce industry (Singh, Singh, Bhunia, & Stroshine, 2002). Organic acids are weak acids that have effective antimicrobial properties (Buchanan, Edelson-Mammel, Boyd, & Marmer, 2004). The antimicrobial classes of organic acids are fully protonated species, which can diffuse into the bacterial cell and cause cell death (Brul & Coote, 1999). These organic acids, which include acetic acid, propionic acid, lactic acid, and citric acid, are naturally found in a variety of fruits and fermented foods, have Generally Recognized As Safe (GRAS) status.

1.2. Food Safety Modernization Act

Small farms with annual sales less than $500,000 are exempt from the 2011 Food Safety Modernization Act's produce safety standards (Food Safety Modernization Act, 2011). However, small farmers' are still responsible for either identifying potential hazards associated with the food being produced and implementing and monitoring preventive controls or demonstrating that they will comply with state, county, or other applicable non-Federal food safety laws. The lack of clear guidelines has been a source of great confusion and frustration for many small farmers. In addition, some farmers markets are starting to require their vendors to meet certain standards for on-farm food safety in order to sell their produce (Miller, 2011). It is evident that growers want to know more about food safety; however, by relying on little more than anecdotal evidence, the produce could be at risk for pathogenic contamination. The investigators have communicated with multiple small farmers around the South East Texas area and there has been an increasing interest to learn about effective post-harvest practices to improve leafy green safety (Personal Communication, Rice University Farmers' Market, 2011).

The objectives of this study were two-fold: (1) Identify specific small farmer concerns regarding post-harvest processing safety using surveys, and (2) Develop an effective, economical and easy to use device to wash, sanitize, and dry leafy greens to improve post-harvest processing practices on small farms.

2. Materials and methods

2.1. Farmer surveys

A twenty-six question survey regarding pre-harvest and post-harvest practices, as well as perceptions of farming practices, was developed as shown in the Appendix. The Human Subjects Committee of the Institutional Review Board of the University of Houston screened and approved the questions and protocol. Participants gave implied consent and were required to be over the age of 18. No identifying information was collected from any participant. The survey was administered to participants at farmers market conferences and farmers markets around the Houston, TX area. The survey was developed as a tool to identify the perceptions and post-harvest practices of small farmers that grow leafy greens and their interest in learning about post-harvest techniques. The survey was administered over a 6-month period.

Questions related to five areas: (1) What vegetables/fruits the farmer grew; (2) What post-harvest practices were employed, if any; (3) What perceptions the farmer had regarding selected post-harvest practices; (4) Farm revenue; (5) Demographic information. This survey was administered to evaluate the need for improved post-harvest practices and to identify farmers in the local area that would be the likely participants for introducing the leafy green washing device.

2.2. Design and construction of the device

The device to sanitize and dry leafy greens was developed using items readily available at local hardware stores (Figs. 1 and 2). The structure was made using a 1-inch PVC pipe for the frame with a 5-gallon food-grade plastic drum to hold the leafy greens with a rotating handle to turn it. A 10-gallon plastic container was cut to design the wash basin which will hold water or sanitizing agent. Holes were drilled in the plastic drum using an electric drill to permit the sanitizing solution to come into contact with the leafy greens. Finally the rotating handle was attached to the plastic drum lid. The device was designed to load the leafy greens in the 5-gallon drum when placed in position A as shown in Fig. 1. Fig. 2 demonstrates position B where the device rests in the wash basin. Multiple wash basins can be designed so that the pre-wash and sanitizing steps can be performed back to back. The device was designed to pre-wash, sanitize, rinse, and dry the leafy greens. Farmers can scale this device based on their needs and amount of leafy greens harvested at one time.

2.3. Validation of device

The efficacy of the sanitation device to reduce the microbial load on leafy greens was investigated in the following two ways: (a) By testing leafy greens inoculated with non-pathogenic surrogates of *Salmonella* Typhimurium (ATCC 53647), *E. coli* (ATCC 10798), and *Listeria innocua* (ATCC 33090); and (b) By enumeration of leafy green microbiota (aerobic plate counts, coliforms, yeasts and molds) before and after using the sanitation device.

2.3.1. Leafy greens

Fresh mixed greens samples were purchased from a local supermarket in Houston, Texas and transported under refrigerated conditions to the Food Microbiology Laboratory at the University of Houston. Pre-cut and pre-washed leafy greens were used and included: arugula, frisee, mesclun, radicchio, and oak leaf lettuce. All leafy greens were kept at 2–5 °C between the time of purchase and initiation of experiments. The experiments were performed within 24 h of purchasing the leafy greens.

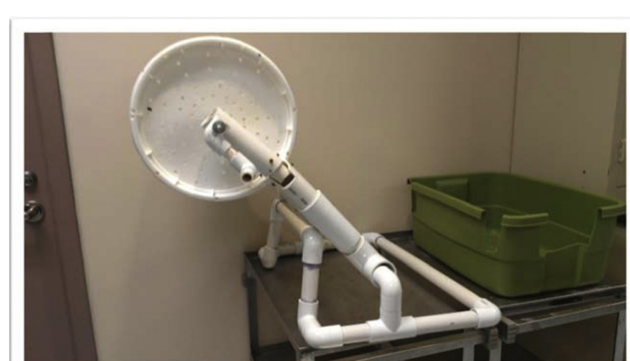

Fig. 1. Leafy greens washer prototype, position A.