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Assessing the effect of washing practices employed in Brazilian processing plants on the quality of ready-to-eat vegetables

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ABSTRACT

This study gathered information on the practices employed in Brazilian processing plants during production of ready-to-eat (RTE) vegetables and evaluated the effect of washing practices on the quality of RTE vegetables produced in these plants. Physicochemical analysis of water included temperature, pH, organic load and chlorine concentration and microbiological analysis included mesophilic bacteria, yeasts and molds, *Enterobacteriaceae*, total coliforms, *Escherichia coli* and *Salmonella*. The ten selected processing plants were clustered in three groups: 1) plants A, B, D, H and I, where washing procedures included immersion in agitated tanks during pre-washing and washing-disinfection and use of disinfectant in the pre-washing step; 2) plant E, where vegetables were washed under running water in the pre-washing step, sodium hypochlorite was used as a disinfectant agent and processing of vegetables was only manual; and 3) plants C, F, G and J, where pre-washing and washing-disinfection were performed by immersion in water, followed by a rinsing step. Chlorine was the most used chemical agent for disinfection of vegetables. A 0.2–1.2 log reduction was achieved by the practices adopted in the plants, highlighting the importance of immediate refrigeration and control measures to avoid post-processing recontamination.

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1. Introduction

Over the last decades, the demand for fresh and convenient foods increased. People have less time to cook at home which reflects the increased popularity of ready-to-eat (RTE) foods, such as minimally processed vegetables (Abadias, Usall, Anguera, Solsona, & Viñas, 2008; Chen, Zhu, Zhang, Niu, & Du, 2010). Moreover, these products have gained ground in restaurants, hotels, fast food chains, catering services and other institutions (Rojas-Grau, Garner, & Martín-Belloso, 2011).

RTE vegetables may be subjected to minimal processing, such as peeling, cutting, slicing, shredding, washing, drying and packaging (Alzamora, Tapia, & López-Malo, 2000; Codex Alimentarius Commission, 2003), resulting in a diversity of products and packaging formats (Jung, Jang, & Matthews, 2014). As the majority of RTE vegetables require no further treatment before consumption, absence of a food borne pathogens killing step can result in a potential public health problem. A number of food borne illnesses associated to fresh produce have been reported (Sivapalasingam, Friedman, Cohen, & Tauxe, 2004) and recent examples are *S.* Newport and *S. Saintpaul* in cucumbers, *S. Enteritidis* in bean, alfafa and spicy sprouts and *Escherichia coli* O157:H7 in ready-to-eat salads, spinach and spring mix (Centers for Disease Control and Prevention, 2015). In Brazil, a number of outbreaks reported between 2000 and 2014 were associated with the consumption of vegetables (Brasil, 2014).

Vegetables can become contaminated with pathogenic microorganisms during harvest and post-harvest, caused by soil, irrigation water, inadequately composted manure, air, wild and domestic animals, human handling, harvesting equipment, transport containers, vehicles, improper storage and packaging (Berger et al., 2010; Harris et al., 2003). Among these operations, washing seems to have a major relevance for the safety of these products.

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Although washing aims to remove debris and reduce microbial load, its effectiveness is limited, and reduction of certain microorganisms to a specific level of safety cannot be assured (Gil, Selma, López-Gálvez, & Allende, 2009). Chemicals added to washing water are helpful, but the antimicrobial effectiveness depends on several factors (Prado-Silva, Cadavez, Gonzales-Barron, Rezende, & Sant'Ana, 2015). For instance, the effectiveness of chlorine at 50–200 mg/L, the most widely used sanitizer for disinfection of fresh produce, is typically less than 2 log CFU (Goodburn & Wallace, 2013).

Recent studies have shown that contamination of washing water used during RTE vegetables processing may lead to spread of contaminants within batches (Jensen, Friedrich, Harris, Danyluk, & Schaffner, 2015; Holvoet et al., 2014; Perez-Rodriguez et al., 2014; Tomás-Callejas et al., 2012; Zhang, Ma, Phelan, & Doyle, 2009). On this matter, cross-contamination during washing may have been the potential cause of many reported food borne outbreaks. Thereby, the knowledge about the washing practices and water characteristics employed in processing plants may help to understand and to prevent the occurrence of cross-contamination during washing of vegetables.

The objectives of this study were to gather information on the practices employed in ten selected Brazilian processing plants located in the State of Sao Paulo during production of RTE vegetables and to evaluate the effect of washing practices on the quality of RTE vegetables produced in these plants.

2. Materials and methods

2.1. Assessment of washing practices in selected Brazilian processing plants during the production of RTE vegetables

Ten major RTE vegetables processing plants, identified as A to J, located in the State of Sao Paulo, Brazil, were selected for the study. Three of them are located in Sao Paulo city and the other seven in inland towns. A questionnaire with 45 items focusing the water usage during processing addressing washing method, water temperature, addition of disinfectant, water volume, amount of vegetables immersed in the water and reuse/discharge of water used in the pre-washing, washing-disinfection and rinsing steps was applied to these plants. Additional information on raw materials reception and storage, centrifugation of washed vegetables, packaging and transportation conditions was also collected. Prior to application in the ten processing plants, the questionnaire (Supplementary material) was validated by application in two plants. A flowchart with the processing steps in the ten visited RTE vegetables processing plants is shown in Fig. 1.

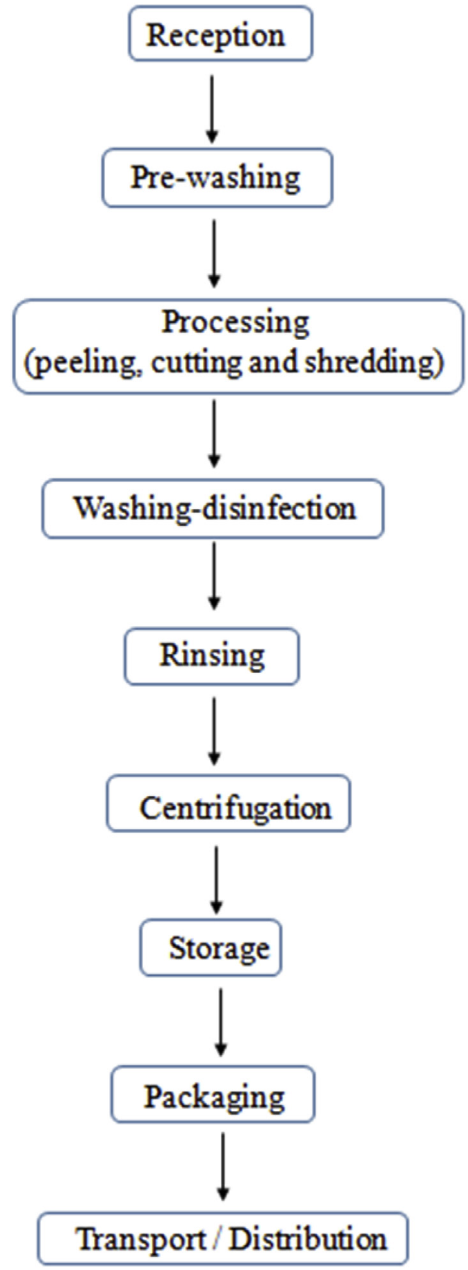

Fig. 1. Flowchart showing the processing steps in the visited processing plants.

2.2. Collection of water and vegetables samples

For the purpose of this study, pre-washing was considered the step in which vegetables were immersed in tanks with water (usually without disinfectant agents) aiming to remove soil and debris, prior to the washing-disinfection step. Washing-disinfection was considered the step in which vegetables were immersed in a tank with water containing disinfectant agents. Rinsing was the step in which pre-washed and disinfected vegetables were washed with clean water to eliminate residues of disinfectants.

A total of 34 water samples (250 mL) were collected in the ten visited processing plants during washing procedures, considering all industries presented a continuous processing. These samples included water from the tap water supply (n = 10), water from pre-washing tanks (n = 9), water from washing-disinfection tanks (n = 10) and water from rinsing tanks (n = 5). Water samples were collected in two bottles, one destined for chemical testing and the other for microbiological analysis. Thirty-six and forty-eight samples of vegetables were collected before and after processing, respectively, and comprised leafy greens [chicory (*Cichorium intybus*), collard greens (*Brassica oleracea*), escarole (*Cichorium endivia*), lettuce (*Lactuca sativa*), parsley (*Petroselinum crispum*), spinach (*Spinacia oleracea*) and watercress (*Nasturtium officinale*)] and other vegetables [beet (*Beta vulgaris esculenta*), carrot (*Daucus carota* subsp. *sativus*), onion (*Allium cepa*), potato (*Solanum tuberosum*), white carrot (*Arracacia xanthorrhiza*) and zucchini (*Cucurbita pepo*)].

2.3. Physicochemical analysis of water samples

Water samples collected from the tanks were tested for temperature (°C), pH, chlorine concentration (mg/L) and organic load

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