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Effect of electrolyzed water treatments on the quality of hand- and machine-peeled yams (*Dioscorea* spp.) during cold storage

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Abstract

The effect of electrolyzed water treatment on the quality of yams by different peeling methods during cold storage was evaluated. The turbidity of the immersion solution increased with extensive storage time while total sugar of yams exhibited the tendency to lessen. The composition of free sugars ranged in the order of fructose > glucose > sucrose except for the samples processed by hand-peeling electrolyzed water and anhydrous storage. The machine peeling showed the suppression of microorganisms that was 1 log cycle lower than hand peeling except EW-2-S. In both hand- and machine-peeled treatments of immersion storage, the effectiveness of the suppression of microorganisms was in the order of 0.6% acetic acid (AA) > EW-1-S > EW-2-S. The results of sensory characteristics of hand-peeled yam were slightly higher than the machine-peeled yam. Overall acceptance of sensory characteristics were: the sample processed by electrolyzed water and hydrous treatment (EW-1-S, EW-2-S) > the sample processed by electrolyzed water and anhydrous storage (EW-1-NS, EW-2-NS) > the sample processed by 0.6%AA and hydrous storage (0.6%AA). The results show that electrolyzed water and hydrous storage is effective on the storage of yams.

Keywords: Electrolyzed water; Yam; Peeling method

1. Introduction

The consumption of various vegetables, including root vegetables, is on the rise as per the demand by the health-conscious consumers. Examples of edible roots are potato, sweet potato, burdock, *Codonopis ianceolata*, yam, lotus root, the root of balloon flower, etc. Yam is a perennial plant with thick underground roots that have been used as food as well as medicine.

Root vegetables are generally distributed as a cold chain that requires minimum processing and best served immediately after washing (Lee, Park, Lee, & Choi, 2003). Although the distribution of the minimally processed root vegetables is generalized, the washing of samples with only water is not sufficient to remove microorganisms and foreign substances in root vegetables after harvest. Furthermore, it may become a causality of secondary contamination by other foods, cooking utensils, etc. (Brackett, 1992). The primary method of reducing microorganisms by washing has its limitations. Various other methods such as the addition of chlorine or hypochlorous acid that inactivates enzymes sensitive to the intracellular oxidation of microorganism have been used. Studies have reported that in washing fruits, approximately 5 ppm residual chlorine can reduce the number of microorganism and 60–80 ppm hypochlorous acid can inactivate pathogens (Parish et al., 2003).

Washing in chlorinated water has been the most widely used method for suppressing microorganisms. However, washing vegetables and root vegetables with chlorinated water was shown to be effective only in reducing pathogens limited to $<2\log \mathrm{cfu/g}$ (Park, Moon, Doyle, Ezeike, & Kim, 2001).

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Although various chemicals and methods deactivating microorganisms have been used (such as of H_2O_2, sodium hypochlorite, chlorine dioxide (ClO_2), sodium bisulfite, organic acid, calcium chloride, ozone, UV, radiation, modified atmosphere packaging), only the minimal effect of germicidal suppressive similar to chlorinated water has been reported (Han, Sherman, Linton, Nielsen, & Nelson, 2000; Lin, Moon, Doyle, & McWatters, 2002). Therefore, it will be beneficial to introduce a new method, both simple to use and economical, that can mediate sufficient germicidal effects.

Recently, as a nonheating processing germicidal method, the electrolyzed water treatment has been drawing substantial interests. Electrolyzed water is generated in a container separated by a polyester membrane during the addition of approximately 500–1000 ppm NaCl to tap water or reverse osmosis water (RO water). Electrolyzed acid water with a pH 2.3–2.7 is generated on the anode side when the oxidation–reduction potential (ORP) reaches +1000 mV and the available chlorine content reaches 10–50 ppm (Kim, Hung, & Brackett, 2000). Moreover, on the cathode side, electrolyzed alkali water with a pH over 11, over −800 mV ORP and the effective concentration of chlorine approximately 0.1–2 ppm is generated. In such manners, electrolyzed acid water has been shown to have a particularly strong bactericidal effect (Nichimoto, Morishita, & Kaithuka, 1996). Numerous studies have shown electrolyzed water to have a strong suppression effect on pathogenic bacteria such as *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Bacillus cereus* and *Salmonella* species (Hsu, Kim, Hung, & Prussia, 2004; Kim, Hung, Brackett, & Lin, 2003). In addition to pathogenic bacteria, it has been reported to suppress hepatitis B virus or human immunodeficiency virus (Morita et al., 2000). Electrolyzed water has also been shown to reduce the germination of molds (Buck, van Iersel, Oetting, & Hung, 2002).

Due to the recent increase in the consumption of vegetables and root vegetables, the consumption of yam has also been growing. The problems of discoloring or browning and the decomposition caused by microorganisms during post-harvest handling and storage have also risen. However, few treatment methods for improving the quality of yams have been studied. The usual handling and storage practices for yams do not include low-temperature storage after harvesting. Without the low-temperature storage or harvesting, its storage is extremely limited as browning or decomposition occurs rapidly. Thus, the yam is marketed primarily by drying and processing it as powder.

In our study, to maintain the quality of yams that are marketed as minimally processed or semi-processed form, the effect of the treatment with electrolyzed water (electrolyzed acid water and electrolyzed alkali water) was examined. Electrolyzed acid water and acetic acid were used as immersing preservatives to investigate the effect on the maintenance of the initial quality and extension of shelf-life of the circulation period of peeled yams. The turbidity of the immersion solution and sugar content of peeled yams, the change in microbial profile, and the overall acceptance of stored samples were then compared and analysed.

2. Materials and methods

2.1. Materials

The yams used in the experiments, were purchased from a wholesale distributor in Sung Nam, Korea, on the day of experiments. All samples were washed once with tap water prior to use to remove soil and other foreign substances. Electrolyzed water produced from GRA 1200 electrolyzed water generator (Kyoungwoo TEC, Korea) was used for this study. Electrolyzed water from the diaphragm system was manufactured under the following conditions: the distance between diaphragms was 1.0 mm and the supplying rate of 20% NaCl was 6 ml/min. The ORP, HClO content and pH at above conditions were 1170 mV, 100 ppm and 2.5, respectively. Electrolyzed water from a nondiaphragm system was manufactured at the following conditions; the distance between diaphragms was 1.0 mm and the supplying rate of 20% NaCl was 4 ml/min. The ORP, HClO content and pH at above conditions were 800 mV, 200 ppm and 9, respectively.

2.2. Treatments

The yams were washed 2–3 times with running water to remove impurities. The yams were either peeled with a hand peeler or machine peeled using a brushing instrument (manufactured by Korea Food Research Institute) and then treated with various solutions as shown in Fig. 1. Subsequently, they were washed by immersing for 30 min in chilled (~0 °C) treatment water. The treatments were as follows: control −0.6% acetic acid (0.6%AA); electrolyzed acid water (pH 2.5–3.0) (EW-1) prepared by a diaphragm method; and electrolyzed alkali water (pH 8.5) (EW-2) prepared by a nondiaphragm method.

The samples subjected to hydrous storage were stored with an immersion solution (0.6%AA, EW-1 or EW-2) at a ratio of 1:1 (w/v), while samples treated with anhydrous storage were taken out of the treatment water, the moisture removed, wrapped with PE film as packages in kg unit, and stored at 2–5 °C. The quality of immersion solutions and samples were evaluated for 30 days without solution exchange. All experiments were replicated three times. During the storage, the samples were classified as either hydrous storage (0.6%AA-S, EW-1-S, EW-2-S) or anhydrous storage (EW-1-NS, EW-2-NS) depending on the presence of the immersion solution.

2.3. Turbidity

The turbidity of immersion solution was evaluated by taking 3 ml samples and measuring the absorbance at 550 nm using a UV/VIS spectrophotometer (V-550, JASCO, Japan).