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Preservation of fruit and vegetable discards with sodium metabisulfite

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ABSTRACT

Two series of experiments were performed to investigate the aerobic preservation of fruit and vegetable discards (FVD) using sodium metabisulfite (SMB). In Exp. 1, metabisulfite was applied at 0, 2, 4, 6, and 8 g/kg FVD for 0, 3, 6, 9, and 12 d. Metabisulfite treatment at 6 and 8 g/kg FVD was highly effective in controlling putrefaction and preserving the nutrient components for 6 and 9 d, respectively. In the pilot-scale experiment (Exp. 2), SMB was applied at 0 and 8 g/kg FVD in a 600-L bucket for 0, 6, and 9 d in an outdoor environment. The SMB treatment was highly effective in maintaining the integrity and freshness of FVD, suppressing microbial proliferation, and preserving the nutrient constituents. Under the conditions of this study, SMB effectively preserved FVD in an aerobic environment, enabling their more efficient long-term recycling through livestock feed or development of value-added products.

1. Introduction

Improper utilization of organic waste can result in water and air pollution (Hanifzadeh et al., 2017). A large proportion of fruits and vegetables are discarded as waste at different parts of the food-supply chain including transportation and distribution, processing, retailing, and at the consumer level (FAO, 2011). Globally, an estimated 30% of all processed fruits and vegetables are lost before reaching consumers (Kader, 2005). These waste resources are usually disposed by incineration or landfilling (Wadhwa and Bakshi, 2013). Both routes have environmental concerns. Although different methods have been proposed for disposal or reuse of fruit and vegetable discards (FVD) produced in packing houses, their utilization as a source of livestock feed appears to be the most promising and viable route for their efficient utilization (Hawkins, 2010). A general administrative pyramid known as the Food Recovery Hierarchy, proposed by the United States Environmental Protection Agency, provides a classification of strategies according to their prioritization for the effective management of food loss and waste (EPA, 2011). In this hierarchy, the most preferred option is adopting measures that prevent waste generation. However, as waste production is an inevitable part of the food-supply chain, the pyramid proposes that the use of the edible waste biomass as animal feed is a more desirable and value-added option than industrial use (e.g., bioenergy recovery) or composting. Landfilling is the least preferable option in this hierarchy as it is associated with serious environmental concerns (Porat et al., 2018).

Earlier investigations supported the use of FVD as a functional feed ingredient for dairy cattle and swine (Esteban et al., 2007). However, an on-site survey we conducted revealed the tendency for discarded fruits and vegetables in the packing house to accumulate for over 1 week before being transported from the packing house to the recycling center. The high content of moisture and simple carbohydrates, as well as the wounding stresses in damaged tissues that cause metabolic activation in FVD accelerate the growth and proliferation of putrefactive microorganisms, attract flies, and promote secondary fermentation (usually associated with offensive odor). These factors collectively accelerate the perishability of FVD (Soliva-Fortuny and Martín-Belloso, 2003; Panda et al., 2016). An efficient preservation technology that allows the safe use of these waste resources for a protracted time is needed.

Sodium metabisulfite (SMB; $Na_2S_2O_5$) is a readily available and cheap powder that is easy and safe to handle (Natskoulis et al., 2018). Metabisulfite is an effective preservative with known bactericidal properties that is widely used in the wine industry as well as for the preservation of dry and fresh fruits, to inhibit enzymatically catalyzed and non-enzymatic browning reactions, and to effectively suppress the microbial growth (Taylor et al., 1986; Jay, 1996). For example, SMB is effective in suppressing browning of olives and their degradation by microorganisms (Arroyo-López et al., 2008; Echevarria et al., 2010). Use of SMB as a silage fermentation modifier provided the fresh-colored, pleasant-smelling silage. The pH is higher than normal silage, but the loss of nutrients due to proteolysis and hydrolysis of carbohydrate

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during fermentation is negligible, likely due to the bacteriostatic action of SMB on microbial fermentation (Cowan et al., 1952; Mahmoud et al., 1976). However, to our knowledge, there is no information concerning the effectiveness and proper level of SMB in the preservation of FVD stored outdoors exposed to air.

We hypothesized that SMB can be used as a preservative to effectively extend the preservation stability of FVD under aerobic exposure. The first objective of the present study was to determine the proper level of SMB load for effective preservation of FVD. The second objective was to demonstrate the effectiveness of SMB application at the pilot scale. A combination of visual, microbiological, and chemical parameters was used as indices to assess the preservative efficacy of SMB.

2. Materials and methods

2.1. Sample preparation and experimental design

Experiment 1 consisted of 25 combinations. Briefly, FVD (approximately 600 kg) were obtained on three consecutive days from a wholesale fruit and vegetable distribution center (E-mart Fresh Center; Icheon city, Kyung-kee province, Korea). The discards were roughly cut and crushed into 30–40 mm pieces, which were thoroughly mixed and randomly divided into five sub-samples. Metabisulfite was either not applied or the powder was added at 2, 4, 6, or 8 g/kg wet FVD. The content of each bucket was mixed thoroughly with SMB for 10 min using a forage mixer (DDK-801 M, Daedong Tech Co. South Korea), and randomly divided into 5 replicate buckets per treatment, with 4 kg FVD in each bucket. This process produced a total of 125 buckets (10 L). The buckets were placed at ambient temperature for 0, 3, 6, 9, and 12 d under aerobic exposure. At these times, the entire contents of each bucket were thoroughly mixed and representative sub-samples were obtained from random locations for the chemical and microbiological analyses.

In Exp. 2, FVD (approximately 2500 kg) were obtained from the aforementioned wholesale fruit and vegetable distribution center on three consecutive days. Metabisulfite was either not applied or the powder was added at 8 g/kg wet FVD. For Exp. 2, FVD cut and thoroughly mixed as described for Exp. 1 were randomly dispensed in four replicate buckets per treatment, with 300 kg FVD in each bucket. To minimize sampling errors, the 2-kg allotments of FVD were each put into a mesh sack (280 mm wide × 560 mm long, 1 mm^2 porosity). The sacks were inserted into three different locations of each bucket: surface (0–5 cm deep), middle (25–40 cm deep), and bottom (55–70 cm deep). The buckets (600-L capacity; height, 102 cm; width 97 cm) were placed outdoor under aerobic exposure for durations of 0, 6 and 9 days. Maximum, minimum, and mean temperatures for the duration of the experiment averaged 28.4, 22.5, and 25.1 °C, respectively. At the designated time for each treatment, the total content of each sack was collected and thoroughly mixed, and representative samples were taken at random for the analyses.

2.2. Visual, microbiological, and physicochemical characterization

Moldy appearance was scored as 0 if no mold was visually evident or 1 if mold was evident (Kwak et al., 2008). The absence and presence of putrid odor was scored as 0 and 1, respectively (Kwak et al., 2008). A panel of three people performed these visual and sensory appraisals. To determine the metabolites produced during the preservation periods, juice extract was obtained by mixing 20 g of each sample with 80 mL of deionized, sterilized water in a sterile plastic bottle. The suspension was shaken for 10 min and then filtered through two layers of cheesecloth (Contreras-Govea et al., 2013). The extract was used for the measurements for pH (HI9321; Hanna Instrument, Portugal) and microbial enumeration. Total bacteria and lactic acid bacteria (LAB) were enumerated using spread plating method on plate count agar and de Man-Rogosa-Sharpe agar, respectively (Difco Laboratories Inc. Detroit, MI, USA). Plates were incubated in a model HK-IB157 incubator (Korea Total Instrument, South Korea) at 36 ± 1 °C for 48 h. Yeast and mold were visually differentiated and enumerated by spread plating method on yeast extract glucose chloramphenicol agar (Difco Laboratories Inc. Detroit, MI, USA). Plates were incubated at 25 ± 1 °C for 3 d for yeasts and 5 d for molds. The detection limit was 2.7 log cfu/g. Water-soluble carbohydrates (WSC) with phenol–sulfuric acid procedure (Dubois et al., 1956) and NH_3–N with phenol–hypochlorite procedure (Chaney and Marbach, 1962) were quantified using an S-1100 UV spectrophotometer (Scinco, South Korea). The standard methods of the Association of Official Analytical Chemists (AOAC, 2012) were adopted for determinations of dry matter (DM; method 930.15), crude protein (N × 6.25; method 990.03), ether extract (method 2003.05), and ash (method 942.05). Neutral-detergent fiber (NDF; inclusive of heat-stable α-amylase and sodium sulfite) and acid-detergent fiber, both exclusive of residual ash, were measured as previously described (Van Soest et al., 1991). Non-fibrous carbohydrates (NFC) were calculated as 100 − [crude protein + NDF + ether extract + ash].

2.3. 2, 2-Diphenyl-1-picrylhydrazyl assay

The liquid phase formed during the leakage of juices and sugars from cut tissues of FVD in Exp. 2 was subjected to the 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging assay, according to the modified procedure of Wootton-Beard et al. (2011). Samples were centrifuged at 4000 × *g* for 5 min at room temperature and the supernatant was collected. A methanolic solution of $DPPH^{\bullet}$ (0.1 m*M*, 3.9 mL) was added to a 50-μL aliquot of the supernatant. The mixtures were kept at room temperature in dark for 30 min. Absorbance was read at 517 nm using an S-1100 UV spectrophotometer (Scinco, South Korea). The percent (%) inhibition of DPPH radical was calculated against the initial DPPH absorbance (without sample).

2.4. Data analyses

Data in Exp. 1 were analyzed in a completely randomized design using PROC MIXED of SAS (SAS, 2003). Treatments were arranged in a 5 × 5 factorial design, resulting in a total of 25 combinations. Tukey's range test was used to identify any significant differences between the least-squares means. Data obtained from Exp. 2 were subjected to ANOVA and the difference between the treatment means was identified using Student's *t*-test. The replicate bucket was considered as the experimental unit. Microbial counts were transformed to logarithm number of colony-forming unit before statistical analysis. Values at $P < 0.05$ were considered significant.

3. Results and discussion

3.1. Initial characterization

Ingredients and chemical compositions of FVD and their proportions used in Exp. 1 and 2 are presented in Table 1. The proportion of each ingredient in the total waste was estimated as the monthly average production of the wastes in the month when the experiment was done. These major ingredients constituted over 95% of total waste in the respective month. Orange and plum constituted the greatest proportion of the total mixed wastes in Exp. 1 and 2, respectively. Among the ingredients analyzed, sweet pumpkin and potato had the highest DM content, and tomato and onion had the lowest DM content. Crude protein content was highest in green onion stalk and lemon, while grape and apple had the lowest crude protein content. Ash content was highest in tomato and green onion stalk, whereas grape and apple had the lowest ash content. Ether extract was negligible in potato and was the highest in sweet pumpkin and green onion stalk. NDF was highest in sweet pumpkin, followed by paprika and green onion stalk, and was lowest in grape and potato.