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Lemongrass essential oil incorporated into alginate-based edible coating for shelf-life extension and quality retention of fresh-cut pineapple

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ABSTRACT

The effects of different concentrations (0.1%, 0.3% and 0.5%, w/v) of lemongrass essential oil incorporated into an alginate-based [sodium alginate 1.29% (w/v), glycerol 1.16% (w/v) and sunflower oil 0.025% (w/v)] edible coating on the respiration rate, physico-chemical properties, and microbiological and sensory quality of fresh-cut pineapple during 16 days of storage (10 ± 1 °C, 65 ± 10% RH) were evaluated. Coated fresh-cut pineapple without lemongrass and uncoated fresh-cut pineapple were stored under the same conditions and served as the controls. The results show that yeast and mould counts and total plate counts of coated samples containing 0.3 and 0.5% (w/v) lemongrass were significantly ($p < 0.05$) lower than other samples. However, the incorporation of 0.5% (w/v) lemongrass in coating formulation significantly ($p < 0.05$) decreased the firmness and sensory scores (taste, texture and overall acceptability) of fresh-cut pineapples. Therefore, the results indicate that an alginate-based edible coating formulation incorporated with 0.3% (w/v) lemongrass has potential to extend the shelf-life and maintain quality of fresh-cut pineapple.

1. Introduction

Fresh pineapple possesses a thick inedible peel and a large crown which takes up storage space and results in higher transportation cost (James and Ngarmsak, 2010). Value addition by processing into a ready-to-eat product is an attractive alternative since consumers will spend less time on food preparation (Rocculi et al., 2009). However, fruit peeling and cutting increase metabolic activities such as respiration rate and delocalisation of enzymes and substrates leading to quality deterioration such as browning, softening, off-flavour and microbial growth, resulting in a short shelf life (Montero-Calderón et al., 2008).

Edible coatings are thin layers of edible material (protein, polysaccharide and lipid) which form directly on the surface of fresh-cut fruit (González-Aguilar et al., 2010). Edible coatings have potential to provide a selective barrier to moisture, carbon dioxide and oxygen, improve mechanical and textural properties, prevent flavour loss, and act as a carrier for different food additives (Tapia et al., 2008). Several studies have been done to determine the effects of edible coatings on fresh-cut fruit such as mango (Chien et al., 2007), papaya (Tapia et al., 2008; Brasil et al., 2012), pear (Oms-Oliu et al., 2008), banana (Bico et al., 2009) and pineapple (Montero-Calderón et al., 2008; Bierhals et al., 2011; Azarakhsh et al., 2012; Mantilla et al., 2013).

The incorporation of antimicrobial agents in edible coatings may widen the functionality of coatings in protecting the fresh-cut fruit from microbial spoilage and thus extend their shelf-life (Raybaudi-Massilia et al., 2008). Recently, essential oils have gained considerable interest as alternatives to chemical preservatives (Mastromatteo et al., 2011). Lemongrass (*Cymbopogon citratus*) is a tall perennial grass, widely cultivated in warm tropical and subtropical regions (Naik et al., 2010). Lemongrass essential oil has antimicrobial activity against a diverse range of microorganisms including moulds, yeasts and gram positive and gram negative bacteria (Naik et al., 2010). Few studies have been done to determine the effects of lemongrass essential oil incorporated into edible coatings for fresh-cut fruit; examples include melon (Raybaudi-Massilia et al., 2008) and apple (Rojas-Graü et al., 2007). However, no published data have been reported on the effects of incorporation of lemongrass essential oil in edible coatings for fresh-cut pineapple.

Thus, the objective of this study was to evaluate the effects of different concentrations of lemongrass essential oil incorporated

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into an alginate-based edible coating on the respiration rate, physico-chemical properties, and microbiological and sensory quality of fresh-cut pineapple during low temperature storage.

2. Materials and methods

2.1. Materials

Fresh pineapples (*Ananas comosus* cv. Josapine) were purchased from Pasar Borong Selangor, Malaysia. Pineapple fruit of regular shape and uniform size without any defect were selected. Fruit at maturity stage 5 (about 50% of eyes were orange-yellow, half ripe fruit) were used. The stage of maturity was determined based on the Malaysian standard by Federal Agricultural Marketing Authority (FAMA) (Shamsudin et al., 2009).

Food grade sodium alginate (Chemtron Sdn Bhd., Kuala Lumpur, Malaysia) was used as a polysaccharide-based edible coating. Glycerol (Sigma–Aldrich, Steinheim, Germany) was applied as a plasticiser. Sunflower oil (Sigma–Aldrich, Argentina) was added as an emulsifier and lipid source. Calcium chloride (Sigma–Aldrich, Steinheim, Germany) was used for gel forming and cross-linking reactions. Ascorbic acid (Sigma–Aldrich, Steinheim, Germany) and citric acid (Sigma–Aldrich, Steinheim, Germany) were used as antibrowning agents. Food grade lemongrass essential oil obtained by steam distillation was purchased from Chemtron Biotechnology Sdn Bhd. (Kuala Lumpur, Malaysia) and used as a natural antimicrobial agent in the alginate-based edible coating formulation.

2.2. Preparation of samples and edible coating formulations

Pineapples, all containers, cutting board, knives and other utensils that would be in contact with pineapple were washed and sanitised with 0.1% (w/v) sodium hypochlorite solution. After washing, the pineapples were peeled manually and cut with a sharp knife into cubes of 2 cm (Rocculi et al., 2009).

An optimised alginate-based edible coating formulation was used, based on our previous study (Azarakhsh et al., 2012) and prepared by dissolving sodium alginate 1.29% (w/v) powder in distilled water while heating with stirring on a hot plate at 70 °C until the mixture became clear. Glycerol 1.16% (w/v) was then added to the formulation, then 0.025% (w/v) of sunflower oil. Different concentrations (0.1%, 0.3% and 0.5%, w/v) of lemongrass essential oil were then incorporated into the alginate-based edible coating formulation. The overall volume for each formulation was 500 mL and this included alginate, glycerol, sunflower oil, lemongrass with the remainder distilled water. All formulations were mixed in an homogeniser (Ultra-Turax T25, Janke and Kunkle, IKa-Labortechnik, Breisgau, Germany) for 5 min at 24,500 rpm to form emulsions and then degassed under vacuum. For a cross-linking reaction necessary for gel formation, a 2% (w/v) calcium chloride solution that contained 1% (w/v) ascorbic acid and 1% (w/v) citric acid was prepared.

2.3. Coating treatment and storage of cut fruit

The pineapple cubes were dipped in the alginate-based formulations for 2 min and excess coating materials were allowed to drip off. The pineapple cubes were then dipped in calcium chloride solution for 2 min. The samples were then air-dried at ambient temperature (26 ± 1 °C) for 1 h. Once coated, the samples were packed in polystyrene trays (10 cubes in each tray) and wrapped with PVC film and then stored at 10 ± 1 °C (González-Aguilar et al., 2004), 65 ± 10% RH for 16 days. Coated fresh-cut pineapple without lemongrass and uncoated fresh-cut pineapple were similarly packed and stored in the same conditions and served as controls. Determinations of respiration rate, weight loss, firmness, colour (L value, chroma, hue angle) and microbial analysis were carried out at 4 day intervals. Evaluation of sensory and morphological properties was carried out after 8 days of storage.

2.4. Determination of respiration rate, weight loss, firmness and colour

Respiration rate was determined using an O_2/CO_2 gas analyser (Mocon Inc., USA) during 16 days of storage. Approximately 10 g of coated or uncoated pineapple cubes were placed in 200 mL glass jars and incubated at 10 ± 1 °C for 1 h. The glass jars had a rubber septum and air-tight screw caps for headspace sampling. The calculation of respiration rate was based on the production of carbon dioxide (mg CO_2/kg h) (Bhande et al., 2008).

Weight loss of pineapple cubes was determined by comparing the weights of samples during 16 days of storage with initial weights by using a digital balance (Presica 4000C, Zurich, Switzerland) and expressing the results as a percentage (Chien et al., 2007).

Firmness of the cubes was evaluated during 16 days of storage with a texture analyser (TAXT2i, Stable Micro System Ltd, England). Penetration tests using a 2 mm diameter stainless steel cylindrical probe, 5 kg load cell and 0.5 mm s^{-1} test speed were employed. The maximum peak measured during the test was taken as firmness (Rocculi et al., 2009).

Colour changes of pineapple cubes during 16 days of storage were evaluated using a Minolta CR-300 chroma meter (Konica Minolta Sensing, Inc., Japan). The instrument was calibrated using a standard white plate. The L value (lightness), C (chroma) and h° (hue angle) were determined for coated and uncoated samples (Antoniolli et al., 2006).

2.5. Microbiological analysis

Total plate counts (TPC) and yeast and mould counts were carried out for microbiological analysis of coated and uncoated fresh-cut pineapple during 16 days of storage (Yousef and Carlstrom, 2003). Total plate counts were determined using the pour plate method and Plate Count Agar (PCA) (Merck, Darmstadt, Germany) as medium. The plates were incubated at 35 °C for 2 days. Yeast and mould counts were determined using the spread plate method and Dichloran Rose-Bengal Chloramphenicol Agar (Merck, Darmstadt, Germany) was used as specific medium for yeast and mould (Olivas et al., 2007). All microbiological analysis was carried out in triplicate and the results were expressed as $\log_{10}$ colony forming units per grams ($\log_{10}$ CFU/g).

2.6. Sensory analysis

Sensory characteristics of pineapple cubes were determined after 8 days of storage by regular pineapple consumers. Thirty individuals aged between 20 and 50 year old who like and eat pineapple frequently were recruited among students and staff of the Faculty of Food Science and Technology, Universiti Putra Malaysia. The male/female proportion of the assessors was equal. The assessors evaluated the colour, appearance, odour, taste, texture and overall acceptability of the samples based on a 9-point hedonic scale (Peryam and Pilgrim, 1957). Sensory tests were carried out in a sensory lab equipped with individual sensory booths in a morning session. The assessors used water and unsalted crackers as palate cleansers between samples. The rest time between samples was 1 min. The samples were presented in plastic containers at ambient temperature (26 ± 1 °C) and codified with three-digit number codes. The order of sample presentation