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Prediction of relationship between surface area, temperature, storage time and ascorbic acid retention of fresh-cut pineapple using adaptive neuro-fuzzy inference system (ANFIS)

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ABSTRACT

Adaptive neuro-fuzzy inference system (ANFIS) was developed for the prediction of ascorbic acid (AA) retention during storage of fresh-cut pineapple as a function of surface area, storage temperature and time. Our results demonstrate that surface area and temperature are the two most important factors influencing the degradation of AA in fresh-cut pineapple during storage. The AA in fresh-cut pineapple with a high surface area is more easily destroyed than that with a low surface area at the same storage temperature. In addition, the ANFIS model with triangular-shaped membership function (trimf) (RMSE = 7.88%; R^2 = 0.95) provides the best prediction accuracy than models with other membership functions (RMSE = 8.97–10.19%; R^2 = 0.91–0.93). Therefore, the high-surface-area fresh-cut fruit should be stored at a relatively low temperature as compared with the low-surface-area produce. The ANFIS model with trimf is an adequate model for the prediction of AA retention during storage of fresh-cut pineapple.

1. Introduction

Pineapple is one of the most important fruit crops of tropical and subtropical regions (Bartholomew et al., 2002), particularly in the form of processed products. Pineapple is a good source of antioxidants because of high levels of phenolics (Hossain and Rahman, 2011). Pineapple juice has been reported as a preferred choice to dissolve phytobezoars, as it contains bromelain, a proteolytic enzyme (Altinbaş et al., 2014). As a ready-to-eat product, fresh-cut pineapple is attractive to consumers (Rocculi et al., 2009). Fresh-cut pineapple is therefore sold at many supermarkets and food distribution outlets in different shapes (cubes, slices, chunks, and cored whole fruit) (González-Aguilar et al., 2004; Marrero and Kader, 2006). Moreover, minimally processed pineapple has a commercial advantage in terms of reduced weight for transport, as bulky inedible crown and peel tissues are removed (Budu and Joyce, 2003). However, cutting pineapple severely affects its shelf life and nutrition quality because of the exposed wound (Watada and Qi, 1999; Soliva-Fortuny and Martin-Belloso, 2003).

From a nutritional perspective, the extent of ascorbic acid retention is widely adopted as a quality criterion for processed pineapple. It is generally observed that if ascorbic acid is well preserved, the other nutrients are also well retained (Lin et al., 1998). Therefore, determining the effect on ascorbic acid during storage by using accurate models is important for the food processing industries. To date, many researchers have studied the degradation of ascorbic acid in foods during storage and processing using mathematical models, such as kinetic models (Burdurlu et al., 2006; Al-Zubaidy and Khalil, 2007; Zheng and Lu, 2011; Demiray et al., 2013; Kurozawa et al., 2014; Remini et al., 2014), Weibull distribution function (Manso et al., 2001; Oms-Oliu et al., 2009; Zheng and Lu, 2011; Djendoubi Mrad et al., 2012; Jiang et al., 2014) and artificial neural network (Lu et al., 2010; Zheng et al., 2011a,b). The adaptive neural-fuzzy inference system (ANFIS) is a multilayer feed-forward network which combines neural network learning algorithms and fuzzy inference systems to construct input-output mapping (Jang, 1993). The fuzzy logic is generally in 89% agreement with results provided by experts. ANFIS has a high training speed, is the most effective learning algorithm and has a

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simple software compared to other learning techniques (Jang and Sun, 1995). In addition, another advantage of this model is faster convergence and better results when applied without any prior knowledge (Altug et al., 1999). Therefore, ANFIS has been used as a modeling tool in agriculture and food technology, for bruise detection (Zheng et al., 2011a,b), food rheology (Karaman and Kayacier, 2011), food processing (Amiryousefi et al., 2011), prediction of yield (Khoshnevisan et al., 2014a) and various extractions from plants and vegetables (Jhin and Hwang, 2014). However, by taking account of recent research, there is no published data on the prediction of ascorbic acid retention in fresh-cut pineapple during storage using ANFIS as a function of storage temperature, time and surface area.

Therefore, the objectives of this research were (1) to evaluate the effect of surface area on ascorbic acid retention during storage of fresh-cut pineapple, (2) to develop ANFIS model to predict ascorbic acid retention as a function of surface area, storage temperature and time, and (3) to compare the performance derived by the use of ANFIS models with different membership functions for predicting ascorbic acid retention during storage of fresh-cut pineapple.

2. Materials and methods

2.1. Materials

Pineapple fruits (*Ananas comosus* L., cv. Smooth Cayenne) were taken from a local market in Jinghua (Zhejiang, P.R. China) and directly transported to the laboratory within 10 mins at 5 °C. The fruits were sorted and graded on the basis of size, shape and maturity, and those with visible infections and mechanical injuries were rejected.

2.2. Preparation of fresh-cut pineapple

Pineapple fruits were washed in an aqueous solution of 1 g L^{-1} sodium hypochlorite at pH 7.0. After washing, the fruit were hand-peeled and cut into cubes of 1–3 cm in a cooled room (8 ± 1 °C; 80% RH), using a sharp knife. Working area, cutting boards, knives, containers and other utensils and surfaces in contact with the fruit during processing were washed and sanitized with 1 g L^{-1} sodium hypochlorite solution to have a maximum sanitizing effect prior to use. The mass (M) was measured by an MP2000-2 balance (±0.001 g) (Shanghai Balance Instruments, China). The surface area (SS) of pineapple cube was in the range from 2048 to 5389 m^2 kg^{-1}. The SS was determined using the equation:

$$SS = \frac{6 \times l^2}{M} \quad (1)$$

where l and M are the length and the mass of pineapple cubes, respectively.

All cut types were washed with sodium hypochlorite solution for 2 min and rinsed for 1 min in tap water. The excess surface water remaining on the products was absorbed with paper towels and they were placed in polypropylene containers (12 cm × 13 cm × 5 cm). The samples were stored in darkness at 5, 8 and 15 °C, and they were analyzed just before packaging (zero time) and after storage for 1, 2, 3, 4, 5 and 6 d. Three pineapple cubes selected randomly from the product were used for the zero time evaluations and 60 pineapple cubes were randomly selected for storage at different temperatures, resulting in a total of 540 pineapple cubes. For each storage time, 3 pineapple cubes per sample were randomly picked and analyzed.

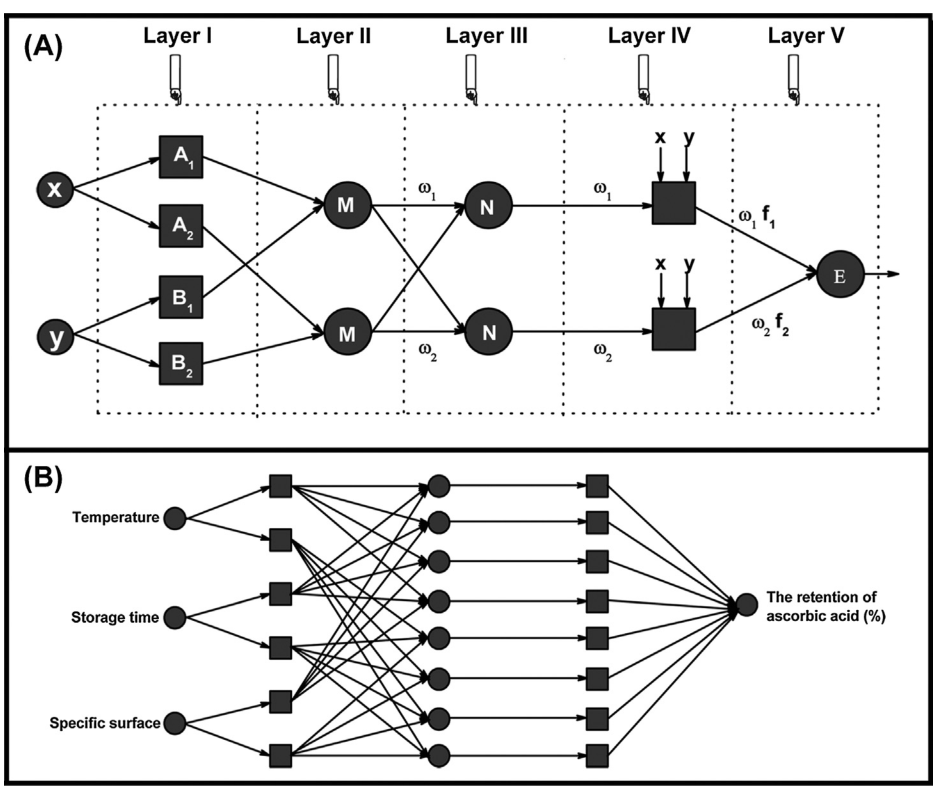

Fig. 1. ANFIS architecture: (A) the first-order Takagi–Sugeno inference system and (B) multiple input single output models consisting of three inputs (temperature, storage time and surface area) and one output (the retention of ascorbic acid) used in this study.