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Evaluation indicators of explosion puffing Fuji apple chips quality from different Chinese origins

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ABSTRACT

In this study, sixteen evaluation indicators of explosion puffing Fuji apple chips from nine different origins in China were analyzed, and the most important evaluation indicators were obtained by analysis of variance (ANOVA), correlation analysis (CA), principal component analysis (PCA) and system cluster analysis (SCA). Results of ANOVA showed that quality of apple chips from different origins showed significant differences ($P < 0.05$). The coefficient of variation (CV) values of sixteen evaluation indicators for apple chips from nine origins were 5.39 %–56.26%. Through CA results, some indicators were correlated to each other within a certain range, such as crude fat content and crispness. Five principle components were extracted through PCA with eigenvalue of over 1, and the cumulative contribution was achieved at 91.06%. Based on the above results, five characteristic indicators of apple chip quality were obtained by SCA. These were crude fiber content, crispness, titratable acid content, production rate and expansion ratio.

1. Introduction

Apple is one of the most frequently consumed fruit. In China, production of commercial apples amounted to 35 million t/year in recent years, of which most (70%) were used for direct consumption, and others (30%) were processed for jam, juice, and dehydrated products (Liu et al., 2012; Woodroof & Luh, 1975). Recently, fruit and vegetable chips have become very important in the diet of the modern consumer because the chips not only can extend shelf life but maintain the original nutrition as well (Zou, Teng, Huang, Dai, & Wei, 2012). Apple chips occupy big market shares in an increasing puffed food market because of being crispy and refreshing, sweet aroma, high nutrition and ease to carry (Dong et al., 2009). There are several processing technologies for apple chips, such as deep fat frying, vacuum frying, freeze-drying and microwave vacuum drying. Among the apple chips processing technologies, explosion puffing drying (EPD) has its unique advantages, no oxygen reduced oxidation in the processing under vacuum drying condition, the processed product is natural and nutritional. EPD means that the material is puffed at higher temperatures between 80 and 130 °C with higher vapor pressure of 0.1–0.3 MPa and dried in vacuum conditions with lower temperature between 60 and 90 °C. A sudden increase in temperature or a sudden decrease in pressure causes water evaporation and expansion in the cells of the materials (Sullivan & Craig, 1984). A puffing process, which performs as an intermediate stage, involves the release or expansion of vapor or gas within the product, either to create an internal structure or to expand and/or rupture an existing one (Antonio, Alves, Azoubel, Murr, & Park, 2008; Hofsetz, Lopes, Hubinger, Mayor, & Sereno, 2007). Compared with the traditional deep-frying and freeze-drying technologies, the product processed with EPD has lower oil content and longer shelf life. Moreover the EPD machine is less expensive, which may promise a bright future for fruit and vegetable drying technology (Ma, Bi, & Wei, 2005).

Parameters optimization of apple chips have been extensive studied (Bi, 2008; Duan & Wang, 2007; DeBelie, DeSmedt, & DeBaerdemaeker, 2000; Dorta & Piotr, 2004; Han, Li, Ma, &Zhao, 2006; Lewicki, Gondek, Witrowa-Rajchert, & Nowak, 2001; Ozilgen, Guvenc, Makaraci, & Tumer, 1995; Sullivan & Craig, 1980). However, the research on quality evaluation of apple chips was mainly about sensory evaluation, instead of quality evaluation

Abbreviations: ANOVA, analysis of variance; CA, correlation analysis; PCA, principal component analysis; SCA, system cluster analysis.

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models. The quality of chips includes sensory quality, physico-chemical nutritional quality and processing quality, which can be evaluated by complex factors, such as product appearance moisture content and Vitamin C (Vc). Different quality factors which were closely related but were relatively independent increase the difficulty of comprehensive evaluation. Therefore, it becomes one of the major tasks to search for a simple method to evaluate the quality of apple chips. Most studies apply principal component analysis (PCA) or cluster analysis to select food evaluation indicators. For example, Bao et al. (2004) studied the selection of navel orange quality evaluation factors using PCA. The result showed that six factors including soluble solids content (or peel redness), titratable acid content, Vc content, juice yield, peel brightness (or peel yellowness), and mean individual fruit weight (or fruit shape index or peel thickness) could reflect the most information on fruit quality of Newhall orange. Xu et al. (2011) adopted cluster analysis to simplify apple quality factors. The result showed that the five most important fruit quality parameters were fruit weight or fruit shape index, fruit firmness, soluble solids content, titratable acid and fruit color. Huang, Yang, and Fang (2003) evaluated the quality of pear varieties using multidimensional value theory, which showed that Vc, soluble solids content and titratable acid were the most important quality indicators.

The above studies filter quality factors only using PCA or cluster analysis separately. There is little research combining these two methods. In this study, nine different Fuji apples producing regions in China were selected to manufacture apple chips by explosion puffing drying technology. Meanwhile, sixteen evaluation indicators were measured for apple chip quality. PCA and system cluster analysis (SCA) were adopted to simplify apple chip quality evaluation indicators, which provided a scientific basis for the research on apple chip quality evaluation.

2. Material and methods

2.1. Materials

2.1.1. Fuji apples

"No. 2 Changfu" is one of the most widely cultivated Fuji varieties. They were picked from nine different origins, including Aksu (Xinjiang province, 80°29′E, 41°15′N), Qixia (Shandong province, 120°83′E, 37°8′N), Lingbao (Henan province, 110°85′E, 34°52′N), Luochuan (Shannxi province, 109°42′E, 35°76′N), Hengshui (Hebei province, 115°72′E, 37°71′N), Taigu (Shanxi province, 122°53′E, 37°42′N), Yingkou (Liaoning province, 122°13′E, 40°39′N), Fengxian (Jiangsu province, 116°57′E, 34°79′N) and Jingning (Gansu province, 105°73′E, 35°51′N).

These apples were picked from trees from middle to late October in 2011. One hundred apples were picked in each location and were made into apple chips using explosion puffing drying technology.

2.1.2. Chemicals

Chemicals used in the experiment were all analytical grade. Blue copperas, methylthionine chloride, sodium hydroxide (NaOH), potassium ferrocyanide, oxalic acid, ascorbic acid, sulfuric acid (H_2SO_4), potassium sulfate (K_2SO_4) and boric acid were provided by Sinopharm Chemical Reagent Beijing Co., Ltd (Beijing, China).

2.2. Preparation of apple chips

Fresh apples were washed, peeled, cut into 5 mm thick slices on a Laboratory Slicer (model FA-200, Nanhai Defeng electrothermal equipment Co., Ltd., Guangdong, China). Apple chips were produced by using the experimental explosion puffing drying equipment system developed by Tianjin Qin-de New Material Scientific Development Co. Ltd. (Tianjin, China). This system can be adjusted to any desired puffing temperature and vacuum pressure. It consists of puffing chamber, vacuum chamber, vacuum pump, decompression valve, air compressor, vapor generator, and manual control panel (Fig. 1). Pre-weighed apple slices (2 kg) were pre-dried at 80 °C for 120 min. Then the materials were puffed at 105 °C for 10 min with a vapor pressure of 0.3 MPa and dried in vacuum conditions with a lower temperature of 80 °C for 120 min (Bi, 2008). The experiment was carried out in triplicate.

2.3. Measurement of evaluation indicators

2.3.1. Color

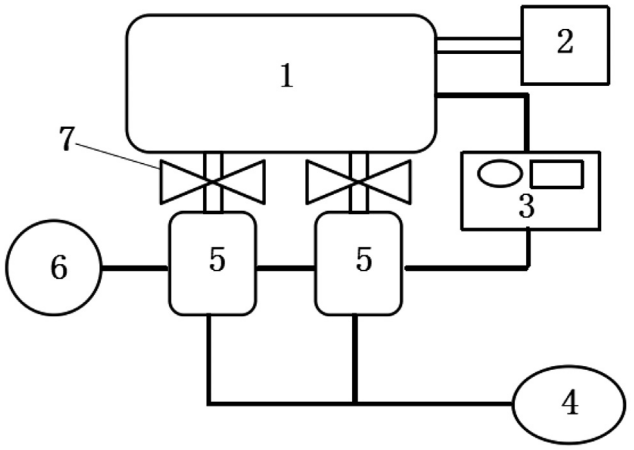
The surface color of the apple chips was measured using colorimeter (D25L, Hunterlab, Virginia, USA). Based on the CIELab color space and after calibration with the white tile and black glass, three equidistant spots were examined on the major axis of each apple chip sample. Since the spot diameter of the instrument was 10 mm, the total area of the slab was 10 cm^2. Triplicate experiments were performed. Three colorimetric evaluation parameters, including lightness (L), green–red hue (a) and blue–yellow hue (b) were measured and calculated to observe color changes. (Lemus-Mondaca et al., 2009).

2.3.2. Crispness and hardness

Crispness of the apple chips was measured using a TA-XT2 texture analyzer (Stable Micro Systems Ltd., Godalming, UK) fitted with a spherical probe (P/0.25). The pre-test, test, and post-test speed were set at 8.0 mm/s, 5.0 mm/s, and 8.0 mm/s, respectively. The deformation ratio was 80%. A force–time curve was recorded and analyzed by the software of Texture Exponent 32 (Surrey, UK) to calculate the peak force, which reflects the hardness of the material. The crispness was calculated as (Anon, 1998; Cruzycelis, Rooney, & McDonough, 1996):

$$C = \frac{k}{F} \tag{1}$$

Where C, k, F refer to crispness of the sample (g^{-1}), specific material constant ($k = 10000$), and hardness of the sample (g), respectively. Triplicates were performed for each batch of samples and the mean value was calculated.



1. Vacuum chamber 2. Vacuum pump 3. Manual control panel 4. Air compressor 5. Puffing chamber 6. Vapor generator 7. Decompression valve

Fig. 1. The diagram of explosion puffing drying equipment.