LWT - Food Science and Technology 70 (2016) 271–279

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Influences of microwave pre-drying and explosion puffing drying induced cell wall polysaccharide modification on physicochemical properties, texture, microstructure and rehydration of pitaya fruit chips

Jianyong Yi, Linyan Zhou, Jinfeng Bi*, Xuan Liu, Chen Qinqin, Xinye Wu

Institute of Food Science and Technology, Chinese Academy of Agricultural Science (CAAS), Key Laboratory of Agro-Products Processing, Ministry of Agriculture, Beijing 100193, China

ARTICLE INFO

Article history:
Received 3 October 2015
Received in revised form
28 February 2016
Accepted 1 March 2016
Available online 3 March 2016

Keywords:
Pitaya fruits
Volume expansion
Glass transition temperature
Cell wall polysaccharides
Extractability

ABSTRACT

The effects of microwave (1.0, 2.0, and 4.0 W/g) and explosion puffing combination drying (MD_x-EPD) on cell wall polysaccharides modification was investigated, and the influences of these modification on the physical and physicochemical properties of pitaya fruit chips were analyzed. Compared with conventional hot air-explosion puffing drying, MD_x-EPD significantly increased volume expansion, and yielded products with superior porous microstructure and crispier texture. The MD_x-EPD dried chips showed faster rehydration rates, as well as decreasing T_g (14.01−15.33 °C). The anhydrouronic acid contents of the water extractable polysaccharide fractions of the MD_x-EPD dried chips were increased by 8−16%, and this, together with the increase in the amount of pectic neutral sugars for the same fractions, were indicative of cell wall polysaccharides solubilization, which could contribute to the improvement of rehydration properties. Data from molar mass distribution suggested the occurrence of cell wall polysaccharide degradation, which could be partially responsible for the decreasing T_g. In conclusion, the relationship between the modification in composition, structure and extractability of cell wall polysaccharides and the alteration in volume expansion, microstructure, T_g and rehydration behaviors confirmed that cell wall polysaccharide played a significant role in the physicochemical and physical properties of pitaya fruit chips.

1. Introduction

Among many fruit chip production technologies, explosion puffing drying (EPD) is an efficient non-fried drying technology with unique advantages. It contributes to a typical porous structure and a pleasant crispy taste, which are both important features for fruit chips (Huang & Zhang, 2012). Other favorable characteristics of explosion puffing are found in color, rehydration, flavor, and production/storage costs (Du et al., 2013). Explosion puffing drying has been applied on many fruits, for example, apple (Yi et al, 2015), mango (Zou, Teng, Huang, Dai, & Wei, 2013), jujube (Du et al., 2013), peach (Lyu, Zhou, Bi, Liu, & Wu, 2015) and banana (Setyopratomo, Fatmawati, Sutrisna, Savitri, & Allaf, 2012), etc.

During explosion puffing drying, the amount of steam that generated in the puffing phase is largely determined by the initial moisture content of a material, which is in most cases around 300 g/kg (Louka & Allaf, 2002). A large amount of generated steam completely disintegrates the porous structure, whereas in the opposite case the material is not well expanded. Generally, prior to explosion puffing drying, hot air drying (AD) is used as a pre-treatment for reducing the moisture content (Louka & Allaf, 2002; Lyu et al., 2015). However, severe shrinkage often occurs during AD pre-drying stage, leading to adverse effects on final qualities, e.g., limited volume expansion. Microwave heating takes place in dielectric materials such as fruit tissues due to the polarization effect of electromagnetic radiation. Besides its high efficiency on dehydration, it was reported that microwave drying (MD) showed an excellent puffing effect on some agro-products (Lee, Lim, Lim, & Lim, 2000; Rakesh & Datta, 2011). In this sense, microwave could be used as an alternative pre-drying method for

* Corresponding author.
E-mail address: jinfengbi_caas@163.com (J. Bi).

http://dx.doi.org/10.1016/j.lwt.2016.03.001
0023-6438/

explosion puffing drying, and this might bring some positive effects on the volume expansion and texture of fruit chips.

Plant cell wall, which plays a important role in the physical properties of many fruit and vegetable products, is made up of complex polysaccharides, phenolic compounds and proteins stabilized by covalent and non-covalent (e.g. ionic) linkages (Caffall & Mohnen, 2009). It is well known that lignin, cellulose and hemicellulose are quite stable during common thermal processing (<100 °C); therefore, a great importance is given to pectin, due to the fact that degradation and structural modification could occur during thermal treatment (Sila, Smout, Elliot, Loey, & Hendrickx, 2006). Pectin is a complex cell wall polysaccharide which generally consists of three domains, i.e. homogalacturonan (HG) (smooth region), rhamnogalacturonan I (RG-I) and rhamnogalacturonan II (RG-II) (hairy regions) (Mohnen, 2008). Some literature have documented that during drying processing, which in most cases is a thermal treatment, the modification of pectin structure is correlated to the physicochemical and physical properties (e.g. texture and rehydration) of a final product. Femenia, Bestard, Sanjuan, Rossello, and Mulet (2000) found that the rehydration property of air-dried broccoli was substantially affected by the amount and structure of cell wall pectic polysaccharides. Latorre, de Escalada, Rojas and Gerschenson (2013) reported that microwave treatment modified the structure of cell wall polysaccharides in such a manner that produced an increase in their hydrophilicity.

The object of this work was to study the influences of cell wall polysaccharides modifications induced by microwave-explosion puffing drying (MD-EPD) on the physicochemical and physical properties of pitaya fruit chips.

2. Material and methods

2.1. Chemicals

Chemicals used in the experiment were all analytical grade. In general, chemicals were provided by Beijing Beihua Chemicals Co., Ltd (Beijing, China). Commercial neutral sugar standards (fucose, rhamnose, arabinose, galactose, glucose, xylose and mannose) were provided by Sinopharm Chemical Reagent Beijing Co., Ltd (Beijing, China).

2.2. Sample preparation

Fully ripened white pitaya fruits (*Hylocereus undatus* Britt & Rose) were purchased from Xinfadi agro-product market in Beijing, China. The fruits were stored at 4 °C before used. Prior to drying, fresh pitaya fruits were taken out of storage, peeled and cut into slices with average thickness of 7.0 ± 1.0 mm.

2.3. Drying process

Hot air drying (AD) was conducted in a convective dryer (DHG-9123A, Jinghong Co., Ltd., Shanghai, China). The drying temperature was 65 °C and the air velocity was 2.05 m/s. Hot air-explosion puffing drying (AD-EPD) consisted of three steps. Firstly, pitaya fruit slices were dried by AD to an intermediate moisture content of 300 g/kg. Then, the semi-dried samples were transferred to an experimental explosion puffing dryer (Qin-de Co. Ltd., Tianjin, China), which was depicted in a previous study (Bi et al., 2015). Prior to explosion puffing, the samples were equilibrated at 90 °C for 5 min. Meanwhile, the vacuum chamber was evacuated by a vacuum pump. The snuffle valves were opened to obtain a rapid pressure drop (<0.2 s) to approximately 40 Pa (absolute pressure) in the puffing chamber, during which the samples were puffed. After puffing, the samples were dried under a continuous vacuum at 65 °C.

Microwave drying (MD) was performed in a laboratory microwave dryer (Sanle Co., Nanjing, China) at a power intensity of 2.0 W/g fresh weight (fw). For MD-EPD treatment, firstly, pitaya fruit slices were dried by MD to a moisture content of 300 g/kg. Three microwave intensities (1.0, 2.0, and 4.0 W/g fw) were used for the MD pre-drying, namely MD_1-, MD_2-, and MD_4-EPD (MD_x-EPD), respectively. Then, the semi-dried samples were removed to the puffing chamber for explosion puffing. Explosion puffing process was performed at the same condition as the AD-EPD. For each drying process, 400 g pitaya fruit slices were used, and the treatments were conducted in triplicates. The drying curves are shown in supplemental material (Fig. S1).

2.4. Physicochemical characteristics

Moisture content was determined by drying a sample to constant weight at 105 °C. Water activity (A_w) was measured by using an A_w meter (AquaLab 3, Decagon Devices, Inc., Washington, USA) (Giraldo-Zuniga, Arévalo-Pinedo, Rodrigues, Lima, & Feitosa, 2006). Glass transition temperature (T_g) was determined using a differential scanning calorimetry (DSC200PC, Netzsch, Bavaria, Germany) (Zou et al., 2013). Total soluble solid (TSS) content was measured by using a refractometer (MASTER-α, Atago Co. Ltd., Tokyo, Japan). Titratable acidity (TA) was determined by titrating a sample with 0.05 mol/L NaOH, and the result was calculated as citric acid equivalent (Chien, Sheu, & Lin, 2007). All the physicochemical characteristic analysis was conducted in triplicates.

2.5. Volume ratio (VR) and bulk density

Volume expansion ratio was measured using a Volscan Profiler (VSP 600, Stable Micro System Ltd., Godalming, UK). VR was calculated using the equation (Bi et al., 2015):

$$VR = (V_a/V_b) \times 100\% \quad (1)$$

where V_a and V_b refer to the volume (mL) of a sample after and before drying, respectively. Bulk density was calculated by dividing the mass of a chip to its corresponding volume. Volume ratio and bulk density determination were performed in triplicates.

2.6. Texture

Texture was measured using a TA.XT2i/50 Texture Analyzer (Stable Micro System Ltd., Godalming, UK) fitted with a ball probe (P/0.25) according to the method described by Lyu et al. (2015). Data were analyzed by the software of Texture Exponent 32 (Stable Micro System Ltd., Godalming, UK). Twelve measurements were performed for each treatment.

2.7. Rehydration

Rehydration properties were analyzed according to the procedure described by Markowski and Zielinska (2013). Briefly, each chip was weighed, placed in a tea drainer, and then immersed in a water bath at 25 °C for various times. At different time intervals, the samples were removed from water. Excess water from the surface was gently wiped off using tissues, and the sample was weighed. The rehydration ratio (RR) was calculated by the following equation:

$$RR = M_r/M_0 \quad (2)$$

where M_0 and M_r are the mass of a sample before and after