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Effect of blanching and drying temperatures on starch-related physicochemical properties, bioactive components and antioxidant activities of yam flours

Xuetao Chen [1], Jun Lu [1], Xia Li*, Ying Wang, Jing Miao, Xinhui Mao, Chengcheng Zhao, Wenyuan Gao**

Tianjin Key Laboratory for Modern Drug Delivery and High-Efficiency, School of Pharmaceutical Science and Technology, Tianjin University, Tianjin 300072, China

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ABSTRACT

The effects of blanching (in boiling water for 1min) and different hot air drying temperatures (40 °C, 60 °C and 80 °C) on the polyphenol oxidase (PPO), peroxidase (POD) and antioxidant activities, main bioactive components, as well as the starch-related physicochemical properties of yam flours were studied. The results of PPO and POD activities, and total flavone and total soluble polyphenol contents showed that blanching was effective to inhibiting enzymatic browning of yams, and the substrate of enzymatic browning reaction may be mainly flavonoid ingredients. The sample of H-40 had higher allantoin and total soluble polyphenol content, stronger DPPH scavenging activity and reducing power. From the results of scanning electron microscopy (SEM), X-ray diffraction (XRD), and Fourier transform infrared (FT-IR), the blanching yams was found contain partly gelatinized starch granules, and had lower crystallinity. The H-40 and H-80 samples had higher RS contents and lower GI values. Furthermore, the protein and soluble amylose contents, solubility and swelling power at 90 °C of the blanching yams were lower than those of the yams without blanching. We can effectively apply these flours in various products based on their characteristics.

1. Introduction

Yams, the tuber of *Dioscorea opposita* Thunb., have been considered as a superior Chinese herb to improve functions of stomach and spleen (SPC, 2015), as well as the fourth major root crop in the world after cassava, potatoes and sweet potatoes (Akinoso and Olatoye, 2013). The major active components in yams are allantoin, phenolic compounds, and others (Muzac-Tucker et al., 1993; Niu et al., 2010). Nonetheless, starch is the predominant fraction of yams, making up approximately 75–84% of the total biomass.

Fresh yams are difficult to store and are susceptible to deterioration during storage. Dried yam slices and flours are the main products in the market, which can be easily stored in the long term and conveniently consumed in these forms. Our previous studies (Chen et al., 2017) have found that hot air drying (HAD) at 60 °C would be a better method for yam drying. Several studies have reported the effect of different drying temperatures on the physiochemical and starch-related properties. (Attanasio et al., 2004; Correia & Beirão-da-Costa, 2012; Falade et al., 2007). Therefore, study on the effects of different drying temperatures on the properties of yam flours is very necessary. In addition to this, fresh-cut processing, such as peeling and cutting, may accelerates physiological deterioration, which leads to yam browning. Browning, decline in the nutritional quality and overall visual quality of yams, severely decreases its market potential. This browning known as enzymatic browning reactions (Bhandari and Kawabata, 2004) is attributed to the oxidation of phenolic compounds by polyphenol oxidase (PPO) and peroxidase (POD). The phenolic compounds were oxidized to quinones, in turn these were polymerized to form brown pigments (Queiroz et al., 2008). Barrett et al. (1991) reported the condition of mechanical injury may result in changes in cell membrane permeability and release of either stored substrates

* Corresponding author.
** Corresponding author.
E-mail addresses: lixia2008@tju.edu.cn (X. Li), pharmgao@tju.edu.cn (W. Gao).
[1] The author contributed equally to this article.

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from the vacuole or bound enzymes from organelles, which may be involved in enzymatic browning.

Some measures have been used to inhibit enzymatic browning of yam during processing. These approaches include sulfur fumigation (Jiang et al., 2013), soaking in chemicals (Krishnan et al., 2010), and electrolyzed water (Jia et al., 2015). However, these measures more or less had chemical residues, to which consumers don't want. Birch et al. reported that the most of the enzyme kept in hot water of 100 °C for 1 min would be inactivation (Birch et al., 2012; Desrosier and Desrosier, 1977). Blanching is an effective and commonly used method, which has relatively low costs.

In this study, according to the previous research (Chen et al., 2017) and practical production, we chose 60 °C, 40 °C (lower than 60 °C) and 80 °C (higher than 60 °C) for yams drying, and determined the effects of blanching and different drying temperatures on starch-related properties, and bioactive components' contents, as well as antioxidant capacity. Finally, aiming toward an effective utilization of these flours in various food products.

2. Materials and methods

2.1. The preparation of dried yam flours

Fresh Chinese yam (*Dioscorea opposita*) was collected from Wen town, Jiaozuo city, Henan Province in China. The yam tubers were washed, peeled, then cut into slices (3 mm thickness). These yam slices were divided into two groups. One group of slices were divided into 3 subgroups, and they were dried in hot air drying oven (DL-101-1S, Tianjin Central Lab Electric Furnace Co., Ltd., China) with air speed 0.15 m/s, at 40 °C for 10h (H-40), 60 °C for 6h (H-60), and 80 °C for 3 h (H-80), respectively. Another group of slices were blanched in a boiling water bath (about 100 °C) for 1 min, the blanched yam slices were divided into three subgroups, and dried in hot air drying oven with air speed 0.15 m/s, at 40 °C for 10h (BH-40), 60 °C for 6h (BH-60), and 80 °C for 3 h (BH-80), respectively.

The dried yam samples were ground in a blender (WND-200, Lanxi Weinengda Electric Co., Ltd. Zhejiang, China), and sieved through a screen (75 ± 4.1 μm) to obtain yam flours.

2.2. Moisture, protein, and total starch content determination

The moisture content of the yam flour was analyzed according to SPC (2015). The protein contents of the yam flours were determined according to Bradford's dye binding method, using bovine serum albumin (BSA) as standard (Bradford, 1976). The total starch content of the yam flour was determined using enzymatic hydrolysis, described by Jiang et al. (2010).

2.3. Apparent amylose content and soluble amylose content

The apparent amylose contents and the soluble amylose contents of yam flour was estimated by using the method of Chen et al. (2016).

2.4. Water-binding capacity (WBC)

Water-binding capacity (WBC) of the yam flour was determined according to the previous reported method (Chen et al., 2017).

2.5. Swelling power (SP) and solubility (SOL)

Solubility and the swelling power were measured according to a method described by Chen et al. (2017).

2.6. Scanning electron microscopy (SEM)

The morphological features of the yam flours were observed with an environmental scanning electron microscope (SEM, Shimadzu SS-550). The dried samples were mounted on a metal stub, coated with gold powder to make the sample conductive, and images were then taken with an accelerating voltage of 1.9 kV.

2.7. X-ray diffraction (XRD)

X-ray diffraction patterns of the yam flours were analyzed according to the previous reported method (Chen et al., 2017).

2.8. Fourier transform infrared spectroscopy (FT-IR)

Fourier transform infrared spectroscopy observed according to the previous reported method (Chen et al., 2017).

2.9. In vitro digestibility

The *in vitro* digestibilities of the yam flours were determined according to the procedure of Chen et al. (2017).

2.10. Polyphenol oxidase (PPO) and peroxidase (POD) activities

The PPO and POD activities were determined by the method described by Jia et al. (2015) with some modifications. Extraction solution was 2 g polyvinyl polypyrolidone (PVPP) mixed with 100 mL sodium phosphate buffer (0.2 mol/L, pH 7.0), and shaken. Yam flour (0.5 g) was placed into test tube in an external ice bath. A total of 2 mL of extraction solution was added to the tube, stirred up the extraction solution for 1 min. The mixture was centrifuged at 12000×*g* for 5 min at 4 °C. This extraction and collection was repeated three times. The supernatant was collected for determinations of the PPO and POD activity.

The substrate was 1.5 mL of 20 mg/mL catechol. Other reaction mixtures included 1.5 mL of 50 mmol/L phosphate buffer (pH 7.0), and 0.2 mL of the enzyme solution. For the blank sample, 0.2 mL of phosphate buffer was used instead of 0.2 mL enzyme solution. The PPO activity was determined as the amount of the enzyme catalyzing a linear increase of 0.001 absorbance per minute per gram yam flour at 410 nm.

The substrate was 25 mmol/L guaiacol and 25 mmol/L hydrogen peroxide dissolved in 0.05 mol/L sodium phosphate buffer (pH 7.0). The reactant contained 2.8 mL substrate and 0.2 mL enzyme solution. For the blank sample, 0.2 mL of phosphate buffer was used instead of 0.2 mL enzyme solution. The POD activity unit (U) was defined as a 0.001 linear increase in absorbance per minute per gram fresh weight at 470 nm.

2.11. Preparation of methanol sample extracts for determination of soluble phenolic, flavonoids, and allantoin contents, as well as antioxidant activity assays

Yam flours (4 g) were placed into test tubes. A total of 15 mL of 80 mL/100 mL methanol was added to each tube, and the tubes were sonicated for 30 min at room temperature. After centrifugation at 3000×*g* for 5 min, the supernatant was collected. This extraction and collection was repeated three times. The 80 mL/100 mL methanol extract was concentrated by vacuum rotary evaporation at 50 °C, dissolved in 80 mL/100 mL methanol to yield 10 mL of total solution, which was used for determination soluble phenolic, flavonoids, and allantoin contents, as well as reducing power. The methanolic yam extract (400 mg/mL) was diluted to the following concentrations for the DPPH radical scavenging test: 10,