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Nutritional and active ingredients of medicinal chrysanthemum flower heads affected by different drying methods

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ABSTRACT

Drying treatments are considered to be the crucial step to preserve the plant's beneficial properties in the post-harvest processes. This paper mainly discussed the effects of four drying methods on quality of medicinal chrysanthemum flower heads, in order to providing the optimal drying conditions for different drying methods. The experimental design included: microwave drying, steam kill-enzyme torrefaction, kill-enzyme torrefaction and oven drying. The results showed that: (1) the contents of flavone and chlorogenic acids significantly increased with the increase of microwave power. However, microwave treatments significantly decreased amino acid content in flower heads. The optimal microwave power and microwave time were about 680–850 W and 8–13 min, respectively. In four drying methods, microwave drying was the most suitable method for keeping the higher contents of flavone, vitamin C and soluble sugar, considering efficiency and the energy consuming; (2) the contents of flavone and chlorogenic significantly increased with the increase of steam kill-enzyme time. However, the contents of amino acid, soluble sugar and vitamin C rose firstly and then decreased with the increase of steam kill-enzyme time. The optima steam kill-enzyme time was about 2–4 min; (3) the contents of flavone, chlorogenic acid and vitamin C increased firstly and then decreased with the increase of kill-enzyme time. Kill-enzyme torrefaction treatments significantly increased soluble sugar content. The optimal kill-enzyme time was about 0.5–1 min; and (4) the optimal oven temperature was about 55–65 °C, which could simultaneously gain the higher contents of active and nutritional ingredients in flowers. So, we should consider the specific conditions of each processing method when we choose the drying method.

1. Introduction

Complex physiological and biochemical changes occur in harvested plant organs by the internal physiological changes and the external environment conditions, which can cause the chemical and nutritional ingredients in organs to reduce or even cause the decay of harvested plants (Cruz and Guadarrama, 2016; Lauxmann and Borsani, 2014). Drying treatments are widely used in the food industry, and considered to be the crucial step to preserve the plant's beneficial properties in the post-harvest processes (Liu et al., 2016; Zhang et al., 2016; Yuan et al., 2015). Currently, many postharvest vegetables and fruits, such as coriander (*Coriandrum sativum* L.) (Sarimeseli, 2011; Divya et al., 2012), broccoli (*Brassica oleracea* L. var. botrytis L.) (Jin et al., 2014), cabbage (*Brassica oleracea* L.) (Phungamngoen et al., 2013), grapes (*Vitis vinifera* L.) (Kyraleou et al., 2016) and kiwifruit (*Actinidia Chinensis*) slices (Orikasa et al., 2014; Jafari et al., 2016) have been successfully preserved by drying treatments.

From previous studies to know, most studies on drying methods have been primarily done on fruits and vegetables. However, few works were also done on medicinal plants. Yang et al. (2007) reported that the microwave drying technology could be suitable for the concentration and dehydration of astragalus (*Astragalus membranaceus*) with the better preservation of astragalus active ingredients. The experiment performed by Wu (2015) indicated that freeze drying could affect physicochemical and associated functional properties in finger citron (*Citrus medica* L. var. *sarcodactylis Swingle*). In the experiment examined by An et al. (2014), different drying methods have significant influences on the quality of chinese magnoliavine fruit (*Schisandrae Chinensis Fructus*), and oven drying should be adopted to substitute sun drying by comprehensive analysis of the cost, content and practicality. However, previous studies have been mainly aimed at searching the suitable drying method, ignoring the systematical studies on the processing methods of medicinal plants.

Medicinal chrysanthemum (*Chrysanthemum morifolium Ramat*) is commonly used in traditional Chinese medicine where they play a role in improving liver function, decreasing inflammation, improving eye-

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sight and serving other anti-inflammatory detoxification roles (Chinese Medicine Dictionary, 2008). In recent years, the flowers of medicinal chrysanthemum act as common materials for functional and healthy tea or beverage due to their unique flavour, colour and health benefits (Yuan et al., 2015). The paper mainly explored the changing laws of active and nutritional ingredients of chrysanthemum flower heads in responses to different drying methods, and evaluated the optimal specific conditions of each processing method, in order to optimize the drying method which simultaneously preserves the higher contents of active and nutritional ingredients in flower heads.

2. Materials and methods

2.1. Equipments

Equipments used in this research are as the following: Microwave oven (Galanz, China), Electric blast drying oven (Teste, China), UV spectrophotometer (Unico, China), Ultrasonic cleaner (Kangjie, China), Electronic balance (Sartorius, China), and water-bath (Shengweili, China).

2.2. Plant material and experimental design

Chrysanthemum seedlings obtained from Anguo Chinese herbal medicine planting base, Hebei province, China, were planted into the farmland. Fresh flowers were collected when 2/3 of the tubular flowers in the flower head were in bloom (Fig. 1). The harvested flowers were divided into four parts and treated with microwave drying, steam kill-enzyme torrefaction, kill-enzyme torrefaction and oven drying, respectively.

2.2.1. Microwave drying

Domestic microwave oven with maximum power output capacity of 850 W was used in this investigation. Fresh flowers samples were arranged as thin layer on the rotatable plate, and treated with four different power level 40%, 60%, 80% and 100% which is equivalent to 340 (W0), 510 (W1), 680 (W2) and 850 W (W3), respectively. Weight loss was recorded at regular intervals of time. Microwave drying continued till the final moisture contents were about 15 ± 0.73% dry basis (Jafari et al., 2016). Microwave time was about 22–24 min, 15–18 min, 10–13 min and 8–10 min at W0, W1, W2 and W3 treatments, respectively.

2.2.2. Steam kill-enzyme torrefaction

Fresh flowers samples were single-layer arranged on meshed trays, and were immediately treated with boiling steam at 100 °C in six different kill-enzyme times of 0 (Z0), 0.5 (Z1), 1 (Z2), 2 (Z3), 4 (Z4) and 6 min (Z5). The samples after steam kill-enzyme torrefation were dried in thermostatic ovens at 65 °C. The final moisture contents were about 15 ± 0.73% dry basis (Jafari et al., 2016). Drying time was about 7–10 h.

Fig. 1. The harvested flowers of medical chrysanthemum.

2.2.3. Kill-enzyme torrefaction

Fresh flowers samples were single-layer arranged on meshed trays, and put into thermostatic ovens to kill enzyme at 105 °C in six different kill-enzyme times of 0 (S0), 0.5 (S1), 1 (S2), 3 (S3), 5 (S4) and 7 min (S5). The samples after killing enzyme were dried in thermostatic ovens at 65 °C. The final moisture contents were about 15 ± 0.73% dry basis (Jafari et al., 2016). Drying time was 24 h.

2.2.4. Oven drying

Fresh flowers samples were single-layer arranged on meshed trays and dried in thermostatic ovens at 55 °C (H1), 65 °C (H2) and 75 °C (H3), respectively. The final moisture contents were about 15 ± 0.73% dry basis (Jafari et al., 2016). Drying time was 24 h.

After treatments, the samples were collected and ground into power and stored in airtight polythene bags until further use. Each treatment had five replicates, and all experiments were performed in duplicate.

2.3. Measurement methods

2.3.1. Malondialdehyde content

Malondialdehyde (MDA) content was determined as described by Feng et al. (2009) with minor modifications. The samples (0.5 g) were homogenized in 5 mL of 20% (w/v) trichloroacetic acid (TCA), and the homogenate was centrifuged at 3500*g* for 20 min at room temperature. The supernatant was used to estimate MDA content. Results were expressed as μmol g^{-1} dried weight (DW).

2.3.2. Phenylalanine ammonia lyase enzyme and cinnamic acid-4-hydroxylase activity

Phenylalanine ammonia lyase (PAL) was determined as described by Liu et al. (2016a,b) with minor modifications. PAL activity was extracted from 0.5 g fresh flower with 5 mL of borate buffer (pH 8.7) containing 5 mmol L^{-1} mercaptoethanol and 0.1% polyvinylpolypyrrolidone. The extracts were centrifuged at 10 000*g* for 15 min at 4 °C. The reaction mixture contained 0.5 mL crude enzyme, 1 mL 0.02 mol L^{-1} L-phenylalanine and 1 mL borate buffer (0.05 mol L^{-1}, pH 8.7). The reaction was incubated at 30 °C for 30 min, and stopped by the addition of 1 mL HCl (2 mol L^{-1}). The activity of PAL was estimated by measuring at 290 nm, and expressed as A h^{-1} g^{-1} DW.

Cinnamic acid-4-hydroxylase (C4H) was determined according to the method described by Lamb and Rubery (1975) with minor modifications. C4H was extracted from 0.5 g fresh flower with 5 mL of 0.1 mol L^{-1} cold phosphate buffer (pH 7.6) containing 0.25 mol L^{-1} sucrose, 0.5 mmol L^{-1} EDTA, 2 mmol L^{-1} mercaptoethanol. Extracts were centrifuged at 10 000*g* for 15 min at 4 °C. The reaction mixture containing 0.2 mL crude enzyme, 0.2 mL 50 mmol L^{-1} transcinnamic acid, 0.2 mL 0.4 g L^{-1} NADPH and 3 mL 0.1 mol L^{-1} phosphate buffer (pH 7.6), was incubated at 30 °C for 30 min, and was stopped by the addition of 0.2 mL HCl (6 mol L^{-1}). The activity of C4H was estimated by measuring at 290 nm.

2.3.3. Photosynthetic pigments content

Carotenoids were extracted from 0.5 g samples with 80% acetone, and calculated according to the method described by Lichtenthaler (1987).

2.3.4. Flavone and chlorogenic acid content

Flavone content was determined according to the method described by He and Liu (2007) with minor modifications. Flavone was extracted from 0.5 g dried flower with 20 mL of 50% ethanol solution in