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Sustainable dehydration of onion slices through novel microwave hydro-diffusion gravity technique

Muhammad Kashif Iqbal Khan [a,*], Muhammad Ansar [b], Akmal Nazir [a], Abid Aslam Maan [a]

[a] Department of Food Engineering, University of Agriculture, Faisalabad, Pakistan
[b] National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan

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ABSTRACT

Onion is a semi-perishable commodity having prominent nutritional value. The deterioration of onion during storage can lead to huge amount of post-harvest losses. Shelf life can be increased through drying, which also facilitates transportation, storage, and packaging due to reduced weight and volume. In the present study, a novel microwave-assisted drying technique called microwave hydro-diffusion gravity was investigated for process optimization and compared with conventional drying techniques. Results indicated that 400 W and 14 min of process were the best combination for drying that removed 80% moisture present in slices. The overall drying time of onion slices was significantly reduced (about six times) compared to hot air oven and freeze-drying methods. MHG dehydration prevented the burning of onions and maintained their sensorial attributes especially color and texture. Similarly, MHG in combination with hot air oven consumed only 0.5 MJ energy as compared to 3.24 and 3 MJ energy used by hot air oven and freeze drying, respectively. In short, results proved that MHG technique is much better than conventional techniques in terms of end product quality and process efficiency.

Industrial relevance: Microwave hydro-diffusion technology is optimized for onion drying. This technology will help in reducing the use of energy and will avoid the loss of water soluble components. These bioactive components have great importance in the field of pharmaceutical. Thus, this technology simultaneously dries the product and extracts the valuable components. It will increase the process efficiency and reduce the processing cost.

1. Introduction

Onion is an important vegetable crop in many countries including China, India, Brazil, and Pakistan (Baroni & Hubinger, 1998). In Pakistan, onion is cultivated on an area of 0.153 million hectares with total production of 2.015 million tonnes (Nabi, Rab, Sajid, Farhatullah, Abbas, & Ali, 2013). It is used to give delicious taste and flavor to a variety of food products. Its strong flavor is due to the presence of organosulfur compounds (Corzo-Martínez, N. Corzo, & M. Villamiel, 2007). It has a good nutritional composition comprising of water (89.11%), proteins (1.10%), ash (0.35%), fats (0.10%), sugars (4.24%), carbohydrates (9.34%), and dietary fiber (1.7%), and it provides 40 kcal of energy. The important minerals including calcium, potassium, and selenium are also present in onion. In addition to its nutritional composition, onion possesses anti-oxidative activity due to polyphenolic compounds (Ly, Hazama, Shimoyamada, H, Kato, & Yamauchi, 2005).

Apart from its use in various food preparations, onion is used for various medicinal purposes. For example, it provides relief from headache, reduces cholesterol level, increases high-density lipoprotein, and helps to control coronary heart diseases. The presence of sulfur compounds in onion helps to prevent growth of cancer cells and is used for the treatment of anemia (Mitra, Shrivastava, & Rao, 2012; Sampath, Bhowmik, Chiranjib, Biswajit, & Tiwari, 2010).

Onion is a semi-perishable commodity and can be deteriorated during storage; with storage losses reaching as high as 66% (Biswas, A. Khair, P.K. Sarkar, & Alom, 2010). The availability of perishable commodities (like fresh vegetables) over longer time periods requires the prevention of unfavorable changes like alteration of food ingredients, loss of taste, aroma, and other undesirable changes (Pérez-Gregorio, Regueiro, González-Barreiro, Rial-Otero, & Simal-Gándara, 2011). Dehydration is one among various preservation techniques for long-term storage of such commodities. Dehydration is a simultaneous process of mass and size reduction that finally makes the food product fit for safe storage. In addition to long-term storage, the reduction in mass and volume of the product also increases the packaging, storage, and transport efficiency (Bebartta, Sahoo, Dash, Panda, & Pal, 2014).

Issues related to conventional dehydration methods have recently drawn attention towards microwave drying of fruits and vegetables. Microwaves are electromagnetic waves that are used to heat the product. In drying of foods with microwave technique, heat is not transferred in the material, but material is induced to heat itself (Bebartta, et al., 2014; Mitra, et al., 2012; Praveen, Umesh, Sukumar, & Ramesh, 2005).

* Corresponding author.
E-mail address: kashif.khan@uaf.edu.pk (M.K.I. Khan).

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However, microwave drying alone can have some issues of uneven heating and non-uniformity of electromagnetic field within the microwave cavity. This can result in textural damages to the dried products (Zhang, Tang, Mujumdar, & Wang, 2006).

Microwave-assisted drying approach overcomes many of the drawbacks of conventional as well as microwave drying processes. In this technique, the product moisture is first removed with microwave heating as a pre-treatment followed by complete drying using some conventional techniques. In addition to improved quality of the end product, it promises speedy operation, cost effectiveness, and energy efficiency (Darvishi, Azadbakht, Rezaeiasl, & Farhang, 2013; Wang, Sun., Chen, Liao, & Hu, 2007; Zhang, et al., 2006). Microwave hydro-diffusion gravity (MHG) is a novel microwave-assisted technique that performs two functions simultaneously, i.e., removal of moisture as well as extraction of functional components from the drying material. Its working principle is based on microwave drying with some modifications (a reactor installed within the microwave cavity as can be seen in Fig. 1). In current study, the novel MHG technique has been optimized for onion dehydration in relation to product characteristics and process efficiency. Furthermore, the results are compared with those of conventional techniques, i.e., hot air and freeze driers.

2. Materials and methods

2.1. Procurement of raw material

Red onions were purchased from local market and manually sorted for similar size, rind color, maturity state, hand touch texture (evaluated by pressing the onion with the fingertips to produce concave deformation), moisture content, and disease free. The sorted onions were cut into slices of equal sizes and stored at temperature of 4 ± 0.5 °C. Uniform and healthy lots were selected for drying and further experiments.

2.2. Determination of moisture contents

The moisture contents were determined by drying 5 g sample in hot air oven at a temperature of 105 °C for 24 h until a constant weight was obtained (AACC, 2000).

2.3. Drying

Drying was accomplished in two steps. In first step, onion slices were pre-treated with MHG technique. After pre-treatment, slices were completely dried using hot air oven and freeze drier.

2.3.1. MHG pre-treatment

During pre-treatment process, onion slices were heated using microwave hydro-diffusion gravity technique (Fig. 1). Onion slices were placed in a reactor installed within a microwave (LG Electronics, South Korea). The slices in reactor were heated with microwaves, which resulted in removal of water vapors from slices. The reactor was connected to a condenser for converting vapors into liquid. The condensed liquid was collected in a beaker and its weight was recorded at specific intervals (2 min). This extract contains various bioactive components, which are not reported in this study. Onion samples (100 ± 5 g) were heated at different microwave powers (160, 240, 320, 400, and 480 W). Heating was stopped when slice color tended to change into brown or before burning of slices through visual observation. In this process, the maximum amount of free water was removed while burning of slices was avoided to maintain quality attributes for further uses.

2.3.2. Complete drying

Onion slices, with and without MHG pre-treatment, were dried through hot air oven (CDS, USA) and freeze drier (Sciquip Ltd., UK). The processing conditions in these dryers were as follows:

- Hot air dryer: a combination of temperature (70 °C) and air velocity of 2 m/s was used to dry fresh and MHG-treated onion slices. The drying process was carried out until no weight change was observed (Wilson, Dattatreya, Chadha, & Sharma, 2012).
- Freeze dryer: fresh and MHG-treated onion slices were dried to 8–10% moisture at −45 °C (abbasi & azari, 2009).

2.4. Drying rate (DR)

Drying rate was calculated to estimate the drying efficiency using following equation:

$$DR = \frac{M_t - M_{t+dt}}{dt} \quad (1)$$

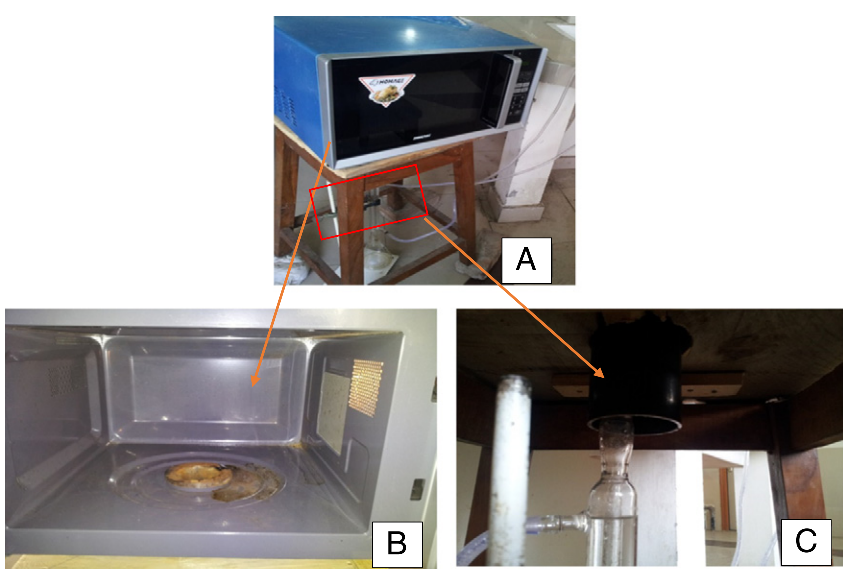

Fig. 1. Microwave hydro-diffusion gravity (MHG) experimental setup used for the dehydration of onions: (A) an overall view of the setup, (B) inside view of modified oven, and (C) bottom view condenser attached to reactor.