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Impact of ultrasound and blanching on functional properties of hot-air dried and freeze dried onions

F. Ren [a, b], C.A. Perussello [a, *], Z. Zhang [a], J.P. Kerry [b], B.K. Tiwari [a]

[a] Food Chemistry and Technology Department, Teagasc Food Research Centre, Ashtown, Dublin 15, Ireland
[b] University College Cork, Western Road, Cork, Ireland

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ABSTRACT

The aim of this study was to investigate the effect of ultrasonic treatment and blanching prior to hot-air drying and freeze drying of onions on the retention of bioactive compounds (total phenolics, total flavonoids, and quercetin). Onion slices were treated either with ultrasound at 20 kHz and different amplitude levels (24.4–61 μm) for 1, 3 and 5 min or with blanching using hot water at 70 °C for 1, 3 and 5 min. The ultrasound treatment improved the retention of bioactive compounds (especially quercetin) and accordingly the antioxidant activity in onion slices dried either by freeze drying or hot-air drying. This is ascribed to the destruction of the original tissue structure by ultrasound and thus higher extraction ability of the studied phytochemicals. Comparing ultrasound treated samples, freeze dried onions had a higher retention of bioactive compounds than hot-air dried ones. Blanched and ultrasound treated dried onions exhibited similar colour change. Therefore, ultrasound treatment is a potential alternative to conventional blanching before drying of onion slices.

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1. Introduction

Dried onions are found in different forms – flaked, minced, chopped and powdered – of extensive demand in several parts of the world (Sarsavadia, Sawhney, Pangavhane, & Singh, 1999).

Sonication is a promising non-thermal technology in the food industry (Tiwari, Patras, Brunton, Cullen, & O'Donnell, 2010). Ultrasound treatments (US treatments) are used to induce desirable chemical and physical changes in foods and can support several processes, such as drying, osmotic dehydration, extraction, mixing, emulsification, filtration, crystallization, thawing and freezing (Marcuzzo, Peressini, Debeaufort, & Sensidoni, 2010). Ultrasonic waves cause rapid compressions and expansions to plant cells, which leads to the formation of bubbles in the sonicated sample and its surroundings. The resulting rapid and short pressure and temperature shifts in the product leads to changes of viscosity and surface tension, destroying cell walls, forming microscopic channels and free radicals, and producing sonochemicals. Scientific evidence exists to support both the positive and the negative impacts of ultrasound treatment on the retention of bioactive compounds in various fruit and vegetables, although the particular effect depends on the process conditions and specificity of the material involved (Mieszczakowska-Frąc, Dyki, & Konopacka, 2016). Advantages of power ultrasound include reduction in processing time, the effective removal of occluded oxygen in juices, and lower energy consumption (Knorr, Zenker, Heinz, & Lee, 2004).

The responses of plants to abiotic stresses, such as US, associated with the production of stress signalling molecules (i.e. reactive oxygen species – ROS) activate the expression of genes involved on the primary and secondary metabolism of the plant (Jacobo-Velázquez, González-Agüero, & Cisneros-Zevallos, 2015). These genes are associated with an increase in the activity of enzymes related with the biosynthesis of secondary metabolites and with the accumulation of secondary metabolites (Jacobo-Velázquez et al., 2015). For this reason, US can be used as an approach to increase the extractability of bioactive compounds (Nowacka & Wedzik, 2016), for instance, found a 12.5% higher extractability of carotenoid from carrots after the application of US at 21 kHz. Ultrasound has also shown higher extraction rates of phenolic compounds from carrot pomace and strawberries (Jabbar et al., 2015). Power ultrasound has also potential as a means of preservation due to the microbial inactivation ascribed to cavitation, as the resulting pressure shifts contributes to cell disruption. Ancillary chemical effects, such as the formation of free radicals as a consequence of

* Corresponding author.
E-mail address: camila.perussello@teagasc.ie (C.A. Perussello).

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the sonochemical reaction, also contribute to the microbial cell disruption (Kadkhodaee & Povey, 2008).

The most popular drying methods for onions are hot-air drying and freeze drying. Hot-air drying involves exposure of the product to a continuously flowing hot air stream. It produces dehydrated products with a shelf life of up to one year, but their quality is usually lower than that of the original foodstuff (Ratti, 2001). Freeze-drying is based on dehydration by sublimation of water from a frozen product. Due to the absence of liquid water and the low temperatures required for freeze drying, most of the deterioration and microbiological reactions are retarded resulting in a final product of high quality (Rawson, Tiwari, Tuohy, O'Donnell, & Brunton, 2011). However, the quality of a dehydrated product depends also on the pre-treatments employed before drying (Negi & Roy, 2000). Hot-water blanching (heating of a product with hot water for a short period) has also been reported to reduce drying time up to a certain operation temperature. Similarly to other thermal processes, blanching affects the concentration of some bioactive compounds in vegetables (Rawson et al., 2011).

Given the possible detrimental effects of blanching on the quality of onions, it is necessary to develop alternative pre-treatments to replace blanching. Despite power ultrasound has been extensively reviewed in fruits, its effects on quality parameters have not been studied in thin sliced onions.

The present study investigated the effect of ultrasonic and blanching pre-treatments prior to hot-air drying and freeze drying on the retention of bioactive compounds (total phenolics, total flavonoids, and individual flavonoids), colour and antioxidant activity of onions.

2. Materials and methods

2.1. Chemicals

Gallic acid, methanol, acetonitrile, ethanol, potassium acetate, aluminium chloride ($AlCl_3$), ferric chloride, 2,2-Diphenyl-1-picrylhydrazyl (DPPH), 2,4,6-tripyridyl-*s*-triazine (TPTZ), hydrogen chloride (HCl), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), and trifluoroacetic acid (TFA) were obtained from Sigma (Sigma Aldrich, Arklow, Ireland). Quercetin 4'glucoside (Q 4′ G), quercetin 3,4′ diglucoside (Q 3,4′ D) and quercetin (Q) standards were purchased from Extrasynthese (Geney Cedex, France).

2.2. Sample preparation

Fresh organic onions were obtained from the Kinsealy Systems field trial carried out at Teagasc, Kinsealy (53° 25 N, 6° 10 W), Dublin, Ireland and stored at 4 °C for a maximum of 24 h prior to analysis. After hand-peeling, onions were vertically sliced (5 mm thickness) using a Berkel 800 meat slicer (Berkel company, Indiana, USA).

2.3. Ultrasound and blanching pre-treatments

One kg of fresh organic onion slices (thickness of approximately 1 cm) were obtained from 10 skin-peeled onion bulbs (variety: Hyskin). In each treatment, 50 g of onion slices were mixed with 100 mL of distilled water at 70 °C in a 200 mL beaker.

Ultrasound (20 kHz) was irradiated to 50 g of onion slices mixed with 100 mL of water at 70 °C with an ultrasonic probe (Ø19 mm) connected to an ultrasonic generator (VC 1500, Sonics and Materials Inc., USA). The energy input was controlled by setting the amplitude of the sonicator probe. Extrinsic parameters of amplitude (power output of 40%, 60% and 80%, equivalent to 24.4, 42.7 and 61 μm) and processing time (1, 3 and 5 min) were varied with pulse duration of 5 s on and 5 s off. The ultrasound probe was submerged to a depth of 25 mm into the sample. All treatments were carried out in triplicate. The ultrasound densities ranged between 0.06 and 0.59 W/mL.

For the blanching pre-treatment, carried out alternatively to the-US treatment, 50 g of onion slices were mixed with 100 mL of distilled water at 70 °C for 1, 3 and 5 min. All treatments were carried out in triplicate.

2.4. Preparation of extracts from dried onions

Control (fresh), sonicated and blanched slices were either freeze-dried or hot-air dried. Hot-air drying of sonicated, blanched and untreated (control) samples was carried out in a laboratory scale hot-air drier (SG96/06/333, Gallenkamp, UK) at 60 °C and 0.3 m/s for 8 h. Pre-treated and control samples of 50 g were placed in a perforated basket (300 × 400 mm; perforation size of 5 × 5 mm), which was inserted in the drying chamber. Each sample was dried separately. Freeze-drying was carried out in a Cuddon freeze-drier (FD80, Cuddon Freeze Dry, Blenhein, New Zealand) at 0.064 mbar for 72 h. After freeze dried or hot-air dried, the samples were vacuum-packed in polypropylene bags and stored at −20 °C until analysis.

The leaching water resulting from the ultrasound and blanching pre-treatments were also freeze-dried or hot-air dried, according to the drying method selected for the onion slices. The dry weights were used to calculate the transfer of material from the onions into the cooking water. For this, the dried onions were blended by a kitchen blender (Kenwood Ltd, Havant, UK). Then, 1 g of the blended sample was mixed with 10 mL of methanol (80%) and homogenised at 24,000 rpm using an Omni-prep multi-sample homogeniser (Omni International, USA). The homogenized sample suspension was shaken overnight with a V400 Multitude Vortexer (Alpha laboratories, North York, Canada) at 1500 rpm at room temperature. The sample suspension was centrifuged (MSE Mistral 3000i, Sanyo Gallenkamp, Leicestershire, UK) at 3000 g for 15 min and immediately filtered through 0.22 μm polytetrafluoethylene filters. The extracts were kept at −20 °C until further analysis.

2.5. Analysis of total phenolics (TPC)

The total phenolic content was determined using the Folin-Ciocalteau method with slight modifications (Singleton, Orthofer, & Lamuela-Raventós, 1999) using a spectrophotometer (Shimadzu UV-1700, Shimadzu Corporation, Kyoto, Japan) at 735 nm. Aqueous gallic acid (10–400 mg/L) was used as standard. The results were expressed as gallic acid equivalents per dry weight of sample (mg GAE/g DW).

2.6. Analysis of total flavonoid content (TFC)

The total flavonoid content was determined by the method described by Lin and Tang (2007) using a spectrophotometer at 415 nm. Quercetin (Q) was used to build the standard calibration curve. The total flavonoid content was expressed as milligrams of quercetin equivalents per gram of dry weight (DW) (mg quercetin/g DW).

2.7. Analysis of antioxidant activity

2.7.1. Ferric reducing antioxidant power (FRAP) assay

The FRAP assay was carried out based on the method by Stratil, Klejdus, and Kuban (2006) with slight modifications. The FRAP solution was freshly prepared on the day of use by mixing acetate

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