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Influence of ultrasound-assisted osmotic dehydration on the main quality parameters of kiwifruit

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ABSTRACT

The aim of this work was to investigate the effect of ultrasound (US) pretreatment, alone and in combination with osmotic dehydration (OD), on texture, color, chlorophyll content, water activity and freezable water content of kiwifruit. Kiwifruit slices were subjected to ultrasonic waves in the bath at a frequency of 35 kHz for 10, 20 and 30 min. Afterwards, the OD was carried out by immersion of samples in 61.5% sucrose solution for pre-established contact period of 0, 10, 20, 30, 60 and 120 min.

From the obtained results it was possible to observe that the effect of US, on overall kiwifruit quality parameters, was not proportionally related to the treatment times. US pretreatment alone positively affected the chlorophyll content, when applied for 20 min, while texture parameter was negatively influenced by all the tested US conditions. When combined with OD, US was able to maintain and sometimes improve the kiwifruit characteristics.

Industrial relevance: Ultrasound is a pretreatment widely used to improve the mass transfer in osmotic dehydration process. The results of this research have demonstrated that the US treatment applied on kiwifruit slices did not promote the deterioration of the product quality. In fact, it was able to maintain or, in certain treatment times, even to improve some quality parameters (e.g. chlorophyll content) of kiwifruit subjected to osmotic dehydration process. Therefore, the ultrasound treatment shows high potentials to be applied at industrial level to reduce the time of osmotic dehydration and to obtain novel products with high quality.

1. Introduction

Power or high intensity ultrasound is a mechanical wave of frequencies above the human hearing, staying in the range between 20 kHz and 100 kHz (McClements, 1995; Mason, 1998; Feng & Yang, 2006). It is based on a rapid series of compressions followed by expansions of the tissue (sponge effect), promoting the alteration of structural and physico-chemical characteristics of food products (McClements, 1995; Fernandes, Gallão, & Rodrigues, 2009). Power ultrasound finds many applications in food processing operations such as drying (Cárcel, Garcia Perez, Riera, & Mulet, 2007; Fernandes & Rodrigues, 2007; Fernandes, Gallão, & Rodrigues, 2008; Fernandes et al., 2009; Schössler, Thomas, & Knorr, 2012; Nowacka & Wedzik, 2016), osmotic dehydration (Simal, Benedito, Sanchez, & Rossello, 1998; Nowacka, Tylewicz, Laghi, Dalla Rosa, & Witrowa-Rajchert, 2014), freezing by induction of nucleation (Comandini et al., 2013), inactivation of microbes and enzymes (Benedito, Ortuño, Castillo-Zamudio, & Mulet, 2015) etc.

During osmotic dehydration (OD), which is the partial dewatering-impregnation process carried out by immersion of cellular tissue in lower water activity (a_w) solutions, several chemico-physical changes in treated samples may occur. OD promotes the a_w reduction (Gianotti, Sacchetti, Guerzoni, & Dalla Rosa, 2001; Silva, Fernandes, & Mauro, 2014) and the freezable water content decrease (Cornillon, 2000; Tylewicz et al., 2011; Cheng, Zhang, Adhikari, & Islam, 2014), allowing to obtain safe products with low/intermediate water content. After OD operation the product is often subjected to drying process in order to obtain high stability. The OD process causes a partial removal of water from food product, that can influence on shortening the drying time (Garcia, Mauro, & Kimura, 2007; Rudy et al., 2013). However the drying time could also be extended due to internal resistance of OD treated foodstuff to mass transfer caused by the solute uptake, which occurs in the osmotic process. Moreover, drying process led also to a greater loss of bioactive compounds due to the high temperature used in the process (El-Aouar, Azoubel, & Xidieh Murr, 2003).

The OD treatment can cause some structural modifications of the processed plant tissue (volume reduction, plasmolysis, loss of cell wall integrity etc.), which consequently may affect its mechanical properties such as texture (Alzamora, Castro, Vidales, Nieto, & Salvatori, 2000, chap. 9; Chiralt et al., 2001; Panarese, Tylewicz, Santagapita, Rocculi, &

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Dalla Rosa, 2012; Panarese, Laghi, Pisi, Tylewicz, Dalla Rosa, & Rocculi, 2012; Kek, Chin, & Yusof, 2013). Since during OD process there is a loss of pigments from the product into the osmotic solution, a modification of the fruit and vegetables color may also occur (Osorio et al., 2007; Tylewicz, Rząca, Rocculi, Romani, & Dalla Rosa, 2010). However, when compared to thermal treated products, better green color maintenance was observed in kiwifruit samples, inasmuch the time to converse chlorophyll into pheophytins was reduced by OD application (Dalla Rosa & Bressa, 1995). In general, the color of plant tissue is a very important food quality feature, which plays a significant role for consumers, influencing their choices. It can be affected by chemical reactions, physical changes and nutritional components decrease (e.g. β-carotene) during technological processes (Perera, 2005; Kutyła-Olesiuk, Nowacka, Wesoły, & Ciosek, 2013; Aadil, Zeng, Han, & Sun, 2013; Pathare, Opara, & Al-Julanda Al-Said, 2013; Nuncio-Jáuregui, Calín-Sánchez, Carbonell-Barrachina, & Hernández, 2014).

Power ultrasound applied before osmotic dehydration process may have an impact on the structure of fruit tissue (Fernandes et al., 2008; Schössler et al., 2012; Nowacka et al., 2014). The "sponge effect" promoted by application of ultrasound results in microscopic channels creation in the fruit tissue. Moreover, this process is often accompanied by breakdown of cell wall, loss of cell adhesion, elongation and disruption of continuous cells etc. (Tarleton & Wakeman, 1998; Fernandes et al., 2008; Nowacka et al., 2014).

It is well known that ultrasound application can enhance the mass transfer during osmotic dehydration of different fruit tissues (Simal et al., 1998; Luchese, Gurak, & Ferreira Marczak, 2015). In our previous work, we demonstrated that the use of ultrasound treatment for 20 and 30 min prior osmotic dehydration had a positive effect on improving water loss and solid gain in kiwifruit tissue (Nowacka et al., 2014). However, to the best of our knowledge, the impact of the combination of these treatments on kiwifruits quality parameters has not been yet investigated. Therefore, the aim of this study was to analyze the selected chemical and physical properties of differently treated kiwifruit samples. In particular, the water activity, freezable water content, texture, color and chlorophyll content of ultrasound treated kiwifruit were investigated. Moreover, the effect of combined treatments (US pretreatment and OD process) on above mentioned physico-chemical kiwifruit characteristics was also investigated.

2. Materials and methods

2.1. Raw material

Kiwifruits (*Actinidia deliciosa* var. *deliciosa* cv Hayward) with homogeneous size and soluble solid content of 12 ± 1°Brix were bought on the local market and stored for 3 weeks in controlled atmospheric condition (4 ± 1 °C, 90–95% RH) until processing. Kiwifruits were hand peeled, cut into 10 ± 1 mm thick slices and subjected to ultrasound and osmotic dehydration treatments.

2.2. Ultrasound (US) pretreatment

The kiwifruit slices were immersed in distilled water and placed in an ultrasonic bath (TransSonic TP 690-A, Elma, Germany, internal dimensions: 135 × 100 × 520 mm) working at a frequency of 35 kHz for 10, 20 and 30 min. Acoustic intensity was expressed as ultrasonic power delivered to the specified mass of ultrasonic treated sample (W/g) The intensity of ultrasound was equal to $8.4 \cdot 10^{-2}$; $9.7 \cdot 10^{-2}$; $10.2 \cdot 10^{-2}$ W/g for time of 10, 20 and 30 min, respectively. The power of ultrasound was calculated using the following equation (Raso, Manas, Pagan, & Sala, 1999):

$$P = MC_p \frac{dT}{dt} \tag{1}$$

where: P is the ultrasonic power, M is the mass of the solution, dT/dt is the increase of temperature, Cp is the heat capacity of the solution.

The slices were covered with the metal net to avoid flow out of the samples. The treatment was carried out at room temperature (25 °C). The ratio of raw material to water was set to 1:4 (w/w), as suggested by Fernandes et al. (2008, 2009). After US treatment the plant materials were blotted with filter paper and subjected to osmotic dehydration. Before and after US treatment the samples mass, dry matter content and water temperature were measured. The temperature increase during the experiments was equal to 3, 5 and 10 °C after 10, 20 and 30 min of US treatment, respectively; this phenomenon was also observed by other authors (Jambrak, Mason, Paniwnyk, & Lelas, 2007; Nowacka, Wiktor, Sledz, Jurek, & Witrowa-Rajchert, 2012; Kek et al., 2013; Nowacka & Wedzik, 2016).

Control samples were prepared by dipping kiwifruit slices (DIP) in distilled water at the same temperature/time conditions of US treated samples, without the application of ultrasound.

2.3. Osmotic dehydration (OD) treatment

Kiwifruit slices were placed in mesh baskets and immersed in 61.5% (w/w) sucrose solution. The osmotic solution: kiwifruit ratio was of 4:1 (w/w), to avoid changes in the solution concentration during the treatment. The final OD time was assessed at 120 min, on the basis of previous works carried out on kiwifruit (Nowacka et al., 2014). The chosen properties were analyzed on kiwifruit samples after established OD time intervals: 0, 10, 20, 30, 60 and 120 min. The process temperature was controlled using thermocouple in the water bath set at 25 °C. The baskets were continuously stirred with a propeller with a speed of 88 rpm. After removal from the solution, the dehydrated kiwifruit samples were rinsed with 200 ml of distilled water for 10 s and blotted with absorbent paper to remove excess of solution. The experiments were conducted in duplicate for each osmotic dehydration process.

All obtained samples are summarised with related abbreviations in Table 1.

3. Qualitative determinations

3.1. Water activity

Water activity (a_w) was measured in the water activity meter AquaLab Series 3TE (Decagon Devices, Inc., USA) at room temperature. The measurements were conducted in triplicate.

3.2. Freezable water content by differential scanning calorimetry (DSC)

Control and treated samples of about 20–30 mg were weighted into a 50 μl hermetic stainless steel pans and analyzed by using differential scanning calorimeter - Pyris 6 DSC (Perkin-Elmer Corporation, Wellesley, USA). An empty pan was used as a reference. The DSC was equipped with a low-temperature cooling unit Intracooler II (Perkin-Elmer Corporation, Wellesley, USA). Temperature and melting enthalpy calibrations were performed with ion exchanged distilled water (mp 0.0 °C),

Table 1
Abbreviations of analyzed samples.

Treatment	Abbreviations	
Osmotic dehydration process	OD	
	Before OD	After OD
Ultrasound treatment for 10 min	US 10	US 10 OD
Ultrasound treatment for 20 min	US 20	US 20 OD
Ultrasound treatment for 30 min	US 30	US 30 OD
Dipping for 10 min	DIP 10	DIP 10 OD
Dipping for 20 min	DIP 20	DIP 20 OD
Dipping for 30 min	DIP 30	DIP 30 OD