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Effect of microwave power and blanching time in relation to different geometric shapes of vegetables

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ABSTRACT

Microwave (MW) blanching (MWB) of vegetables has been applied in food industry as alternative to conventional treatment. Therefore, this study was aimed to evaluate the efficacy of MWB in terms of peroxidase (POD) inactivation, by applying various process conditions (MW power and process time) to different vegetables (potatoes, savoy and white cabbage), mimicking the most common geometric shapes (cylindrical, cubed, parallelepiped and slabbed). In all 3-D shapes, POD inactivation was initially achieved at the core of sample and gradually extended toward the periphery with the increase of process intensity. However, MWB appeared to be not suitable for reaching the temperature level required for the POD irreversible inactivation on the surface of vegetables, neither in 3-D nor in slabbed shape.

The optimal blanching conditions (POD residual activity $< 10\%$), determined by response surface methodology analysis were: 160 W for 120 s for cylinder and large parallelepiped samples; 160 W for 75 s for cube sample; 350 W for 45 s for small parallelepiped sample. Contrariwise, in vegetables mimicking slab geometric shape the POD inactivation did not reach the optimal endpoint of blanching treatment, neither by increasing the MW power nor extending the process time.

1. Introduction

Blanching is a mild heat treatment widely applied in food industry prior to freezing, canning or drying fresh vegetables and fruits (Ranjan, Dasgupta, Walia, Chand, & Ramalingam, 2017) in order to extend the shelf life of the products, stabilizing their nutritional quality and texture. This unit operation is mainly aimed to inactivate both microorganisms and quality changing enzymes responsible for deterioration reactions that contribute to off-flavors, odors, undesirable color and texture, and breakdown of nutrients (Manpreet, Shivhare, & Ahmed, 2000; Xiao et al., 2017).

Among the naturally occurring enzymes, peroxidase (POD) is used in the food industry as an indicator of blanching adequacy, due to its high thermal resistance (Ramesh, Wolf, Tevini, & Bognár, 2002). Based on the type of technique applied, blanching can be categorized as: i) wet blanching, which is achieved by dipping vegetables in hot water, hot solutions (containing acids and/or salts) or steam (Kidmose & Martens, 1999); ii) dry blanching, which is carried out using microwaves (MW) (Ramesh et al., 2002), infra-red radiation (Kalathur, Girish, & Hebbar, 2013) or high pressure (Castro et al., 2008).

In the last decade, the increasing consumer demand of minimum treated and fresh-like products lead food industries to the application of novel technologies for inactivating enzymes with minimum deleterious effects on texture, flavor and nutrients (Aziz, Mahrous, & Youssef, 2002; Demirdöven & Baysal, 2008). MW blanching (MWB) is of great interest for both academic and industrial point of view, and it has been applied on different vegetables such as potatoes (Severini, Baiano, De Pilli, Romaniello, & Derossi, 2004), broccoli (Eheart, 1967), carrots (Soysal & Söylemez, 2005), and bell peppers (Ramesh et al., 2002). In comparison with conventional wet blanching, MWB allows: i) greater nutrients retention due to the reduction of leaching losses during treatment; ii) faster heating rate (heat is internally produced, whereas in conventional blanching heat is transferred by conduction from the product surface to the inner part); iii) greater penetration depth; iv) space savings because the equipment takes up a smaller area (Benlloch-Tinoco, Igual, Rodrigo, & Martínez-Navarrete, 2015).

As described in literature (Chavan & Chavan, 2010), the effectiveness of MWB depends on: i) process conditions [i.e. MW frequency and power, heating speed, mass and mobility of the product inside the oven (rotation/non-rotation)]; ii) vegetable characteristics [i.e. dielectric properties, penetration depth, moisture content, density, physical geometry (size, thickness, shape), surface to volume ratio and specific heat]. The non-uniform temperature distribution during MW heating has been extensively studied (Geedipalli, Rakesh, & Datta, 2007;

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Gunasekaran & Yang, 2007; Manickavasagan, Jayas, & White, 2006; Vadivambal & Jayas, 2010) and several researchers have developed mathematical models in order to predict temperature distribution in the MW heated food (Campanone & Zaritzky, 2005; Ni & Datta, 1999; Vilayannur, Puri, & Anantheswaran, 1998; Yang & Gunasekaran, 2004). Among these, Van Remmen, Ponne, Nijhuis, Bartels, and Kerkhof (1996) tweaked simple models in order to obtain a qualitative prediction of temperature distributions in three basic geometries (i.e. sphere, cylinder and slab) for MW energy penetration in food products.

Brewer and Begum (2004) proved that microwave power levels applied for different times affected POD inactivation in broccoli, green beans and asparagus. Despite these researches on MWB, no studies have yet been carried out changing both the process parameters and the geometry of vegetable matter. Therefore, the aim of this study was to evaluate the efficacy of MWB, in terms of POD inactivation, applying various process conditions (i.e. MW power and process time) to different vegetables namely potato and leafy vegetables (savoy cabbage and white cabbage) mimicking the most common geometric shapes and assess the effect on selected quality attributes.

2. Materials and methods

2.1. Sample preparation

Potatoes (*Solanum tuberosum* L. var. agria), savoy cabbage (*Brassica oleracea* L. var. sabauda) and white cabbage (*Brassica oleracea* L. var. capitata) were purchased from a local supermarket and stored in a refrigerator at 4 °C. Before the experiments, the samples were taken out and equilibrated to room temperature (25 °C) overnight. Potatoes were washed, hand-peeled, and cut into cylindrical- and cuboid-shaped. The cylinder samples (Cy) had a diameter of 24 mm and a height of 9 mm. For cuboid-shaped, the samples were prepared with dimensions (length × width × height) of: i) 18 × 18 × 18 mm (cube, Cu); ii) 36 × 18 × 18 mm (large parallelepiped, Lp) and iii) 36 × 9 × 18 mm (small parallelepiped, Sp). Savoy cabbage and white cabbage leaves were used to mimic slab-shaped (Sl_s and Sl_{wc}, respectively).

2.2. Microwave blanching

A household microwave oven (Whirlpool, Talent, 3D System 2.45 GHz, working with standing wave), provided with a glass turntable plate, was used to blanch the samples. In order to study the effect of MW power and process time on the inactivation of POD (for the different tested geometric shapes) using the minimum number of experimental trials, an experimental design based on a central composite design with quadratic model was applied. The dependent variable (y) measured was the POD residual activity, expressed as the percentage with respect to the initial value. The variance for each factor evaluated was partitioned into linear, quadratic and interactive components and was represented using the second order polynomial function as follows:

$$y = b_0 + b_1x_1 + b_2x_2 + b_{11} \times {}_1^2 + b_{22} \times {}_2^2 + b_{12}x_1x_2 \qquad (1)$$

The coefficients of the polynomial were represented by b_0 (constant term), b_1 and b_2 (linear coefficient), b_{11} and b_{22} (quadratic coefficient) and b_{12} (interactive coefficient). The significance of all the terms in the polynomial function was assessed statistically using the F-value at a probability (p) of 0.001, 0.01 or 0.05. The regression coefficients were then used to generate contour plots from the regression models. The experimental design and the statistical analysis were performed using Minitab 17.1 (Minitab Inc., Pennsylvania, USA).

Response surface methodology was used to verify the presence of combined effect between the MW power and the process time (independent variables), which were designed to vary between 50 and 350 W and between 45 and 120 s, respectively. These variables were coded as X1 and X2 respectively and each had three levels (−1, 0, and +1). A total of 11 running factorial points, including three replicates of the center point, were carried out in random order according to the central composite design. The level of variables for (x1 and x2) and (X1 and X2) are shown in Table 1.

Table 1
Matrix of experimental central composite design for determining optimum blanching parameters (MW power and process time). The effect of MW power and process time on peroxidase (POD) residual activity was evaluated for different geometries [cylinder (Cy), cube (Cu), large parallelepiped (Lp), small parallelepiped (Sp) made of white potato, and slab made of savoy cabbage (Sl_s) or white cabbage (Sl_{wc})].

Treatment trial	MW power (W)	Process time (s)	POD residual activity (%)					
	X1 (x1)	X2 (x2)	Cy	Cu	Lp	Sp	Sl_s	Sl_{wc}
1	50 (−1)	45 (−1)	94	91	98	80	99	80
2	50 (−1)	75 (0)	113	52	80	87	88	61
3	50 (−1)	120 (+1)	55	29	58	46	77	46
4	160 (0)	45 (−1)	47	31	48	34	94	93
5	160 (0)	75 (0)	27	13	33	19	87	58
6	160 (0)	75 (0)	28	8	29	25	88	60
7	160 (0)	75 (0)	36	13	38	22	86	55
8	160 (0)	120 (+1)	11	11	10	21	80	48
9	350 (+1)	45 (−1)	27	13	16	10	67	31
10	350 (+1)	75 (0)	7	7	7	4	50	22
11	350 (+1)	120 (+1)	7	7	8	5	22	14

For each trial, about 50 g of fresh weight sample (w_{fw}) were treated using the three different MW power (50, 160 and 350 W) for each of the three process time (45, 75 and 120 s). After MWB, the samples were immediately cooled in ice-water for 5 min before testing to avoid the effect of remaining heat. For each tested geometric shape an untreated sample was taken as reference. Samples were analyzed for POD activity and firmness immediately before and after MWB.

2.3. Peroxidase activity assay

Qualitative POD activity determination was carried out as described by Pan et al. (2005). After MWB, the processed potatoes (Cy, Cu, Lp, Sp) were cut lengthwise into two equal pieces. The 1% guaiacol solution and 1% hydrogen peroxide solutions were sequentially applied to the cut surfaces of potato samples and on the surfaces of leafy vegetables and were examined for color development after 5 min. Active POD reacted with these substances to produce a reddish-brown coloration. The portion of the sample which remained colorless (no red color) indicated where POD inactivation occurred. Samples were immediately photographed by using a Nikon Camera (Nikon COOLPIX P510).

POD activity was quantitatively measured according to the method described by Neves, Vieira, and Silva (2012), with modification. Samples, added to potassium phosphate buffer (0.1 M, pH 6.5) with 1:2 (w_{fw}/v) extraction ratio, were homogenized with an Ultra-Turrax T25 (Ika-Werke GmbH & Co, Staufen, Germany) in ice bath for 1 min. The suspension was centrifuged in polypropylene tubes for 10 min, at 18.000 × *g* in a Beckman centrifuge (Model J2-21. Beckman Instruments Inc., Palo Alto, CA., USA) at 4 °C and the supernatant was used as enzyme extract for POD assay.

POD activity was measured at 20 °C as follows: 0.02 mL of enzyme extract was added to 3.48 mL of substrate solution (prepared daily), which contained 99.8 mL of 0.1 M potassium phosphate buffer (pH 6.5), 0.1 mL of 99.5% guaiacol (Sigma Aldrich, Milan, Italy) and 0.1 mL of 30% hydrogen peroxide (Sigma Aldrich, Milan, Italy).

The increase in absorbance at 470 nm was recorded for 1 min, using 10 mm path-length glass cuvettes and an UV–visible spectrophotometer (Shimadzu UV-2450, Milan, Italy). The reaction rate constant was determined from the slope of the linear portion of the plot absorbance vs time and was used to calculate the conversion rate of substrate and product, taking into account that the (molar) extinction coefficient for