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Comparison study of conventional hot-water and microwave blanching on quality of green beans

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ABSTRACT

Microwave blanching of green beans (*Phaseolus vulgaris* L.) was explored as an alternative to conventional hot-water blanching. Batches of raw pods were treated similarly to an industrial process employing a hot-water treatment but using a microwave oven for blanching. The effects of microwave processing time and nominal output power on physical properties (shrinkage, weight loss, texture, and color), enzyme activities (guaiacol peroxidase, L-ascorbate peroxidase, and catalase), and ascorbic acid content of pods were measured and modeled by first-order kinetics. Inactivation of peroxidase (POD) was the best indicator to assess the efficiency of microwave-blanching of green beans. No significant differences in product quality were found between hot-water blanched and microwaved pods at optimal processing conditions. Furthermore, since shorter processing times and higher ascorbic acid retention were found, microwave processing of green beans can be a good alternative to conventional blanching methods.

Industrial relevance: Microwave blanching of green bean pods has been proved as a reliable alternative method to the conventional heating process used in the vegetable canning industry. The overall quality of the product processed by microwave heating under optimal conditions was comparable to that of the current industry process. The microwave treatment of pods, in addition to an effective enzyme inactivation in less processing time, led to a better retention of ascorbic acid.

1. Introduction

Blanching is a heat treatment widely applied in the agro-food sector and particularly important in the processing of green vegetables. Its main goal is to inactivate the enzymes involved in the spoilage of fresh vegetables (Williams, Lim, Chen, Pangborn, & Whitaker, 1986). Other objectives of blanching are to reduce the microbial load of products so as to improve its conservation, to soften tissues for an easier canning step and a shorter cooking time, and to eliminate intracellular air to prevent oxidation (Barrett & Theerakulkait, 1995; Poulsen, 1986; Ramesh, Wolf, Tevini, & Bognár, 2002). As a further consequence, blanching also lowers somewhat the mass of vegetables, so the process profitability can be affected by overtreatment. Commercial blanchers used in the vegetable canning industry are relatively intensive in energy and water consumption. Energy utilization is affected by the equipment used and also by the configuration of the following freezing step. Furthermore, conventional blanching produces wastewater which can reduce the nutritional value of vegetables by leaching of soluble compounds, and subsequently increase the pollutant charge (Poulsen, 1986; Williams et al., 1986).

The increase in demand of minimally processed and high-quality products has stimulated the development of new technologies that reduce the adverse effects of vegetable processing (Picouet, Landl, Abadias, Castellari, & Viñas, 2009; Ramesh et al., 2002). Microwave blanching of vegetables is one of these technologies which seem to provide a better nutrient retention than other conventional methods (Günes & Bayindirli, 1993; Kidmose & Martens, 1999). Thus, microwave processing may be an attractive alternative because of advantages such as a lower processing time or an improved heating efficiency. Moreover, since microwave blanching is considered as a dry technique, the volume of wastewater generated could be diminished and therefore losses of water-soluble nutrients could be minimized (Günes & Bayindirli, 1993; Quenzer & Burns, 1981). Several studies on microwave blanching of vegetables and fruits have been reported. Brewer, Klein, Rastogi, and Perry (1994) considered the effect of different blanching methods on the ascorbic acid content and the peroxidase activity in 225 g-batches of green beans, and they concluded that a 3-min microwave treatment at 700 W resulted in a product similar to that obtained by steam blanching. Muftugil (1986) observed that the time to complete the peroxidase inactivation in green beans was less with microwave blanching than with water and steam treatment, whereas a higher greenness remained with the two latter methods. Brewer and Begum (2003) studied the effects of power and irradiation time on ascorbic acid, color, and peroxidase activity in microwave blanching of green beans among other vegetables. Compared to raw unblanched samples, they found that the optimum conditions (2 min at 490 W, or 1 min at 700 W) led to a peroxidase activity reduction up to 88%, and an ascorbic acid retention of about

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70%. However, despite all of these studies, comparison studies of microwave blanching with conventional industrial blanching are few.

The objective of this work was to evaluate the effects of microwave treatment on green beans compared with those of conventional industrial blanching. To this end, microwave and hot-water blanched pods were characterized in terms of weight loss, shrinkage, texture, color, enzyme inactivation, and ascorbic acid retention. Furthermore, kinetic models were developed considering the time–temperature profiles. The optimal conditions of microwave blanching of green beans were selected among those providing a final product with characteristics similar to those of the industrially blanched pods.

2. Material and methods

2.1. Raw material and conventional blanching

Raw (RM) and industrially-blanched (IB) green bean pods (*Phaseolus vulgaris* L. cv. Ebro) were kindly supplied by a vegetable processing company from Navarra (Spain). The industrially processed pods are selected, washed, and cut up into small parts (about 6 cm length and 5.5 g weight). These pieces are then treated in an integrated blancher–cooler (Urtasun PHR series, Spain) where they are preheated at 65 °C for about 100 s, blanched in water at 92 °C for 200 s, and finally cooled in water for 300 s. The equipment processing capacity ranged from 800 to 1000 kg/h for green beans. Some characteristics of fresh unblanched and industrially blanched green bean pods are shown in Table 1.

2.2. Microwave blanching

Fresh pods were directly collected from the stock of selected raw material just before industrial processing, and then samples were transported refrigerated to the laboratory facility. After that, raw pods were treated in the laboratory in a similar way to the industrial process, with the exception of the blanching step which was performed using a microwave oven (Whirlpool AVM-683, Norrköping, Sweden). Green bean pods were selected, cut into pieces of 6 cm, and then washed and drained. Batches of about 150 g of thus pretreated pods were placed in the oven forming a layer on a glass bowl (115 mm diameter, 65 mm height). Two beakers, each one containing 50 mL of water, were also put in the oven to provide a water-saturated atmosphere and to protect the magnetron from overheating. Different samples were microwaved for each combination of nominal power level (650, 750, and 900 W) and processing time (50, 100, 150, 200, 250, and 300 s). Internal temperature of samples was measured just after each treatment with a fast-response thermocouple (Cole-Parmer, Digi-Sense 08505-86, Chicago, U.S.A.) attached to a digital thermometer (Hanna Instruments HI93531, Padua, Italy). Thus, once the heating treatment was finished, the temperature probe was immediately inserted within the sample and the maximum memory reading achieved was considered the actual temperature. The temperature of each sample was usually recorded in less than 5 s. After blanching, pods were cooled with flowing water for 300 s and then drained.

Oven calibration was performed according to the EPA Method 3015A (EPA, 2007). The obtained values were 585.6 ± 7.3 W, 670.5 ± 7.2 W and 807.0 ± 6.1 W for the low (650 W), medium (750 W) and high (900 W) power levels, respectively. For these conditions, the power/load ratio was 3.9, 4.5 and 5.4 W/g in increasing order of power output. No significant variations in measured power were observed throughout the study. From now on, the actual output power levels are denoted by the corresponding nominal values (i.e. as displayed in the oven control unit).

Table 1
Characterization of the fresh and industrially-blanched (hot-water treatment) green bean pods.

Parameter	Raw pods	Blanched pods
Firmness (N)	177.9 (22.7)	148.0 (26.9)
Lightness L^*	68.12 (2.77)	58.19 (2.60)
Redness a^*	−13.68 (0.98)	−15.98 (0.98)
Yellowness b^*	23.74 (1.23)	23.02 (1.72)
Hue angle (°)	119.96 (2.19)	124.78 (2.59)
APX activity (μmol kg^{-1} s^{-1}) [a]	12.45 (1.35)	3.60 (0.55)
CAT activity (mmol kg^{-1} s^{-1}) [b]	4.175 (0.208)	ND
POD activity (μmol kg^{-1} s^{-1}) [c]	18.78 (1.15)	ND
Ascorbic acid (mg kg^{-1})	214.2 (11.7)	102.1 (4.3)

Each value is the mean (and standard deviation).
ND = not detected.
[a] Limit of detection = 1.16 μmol kg^{-1} s^{-1}.
[b] Limit of detection = 0.010 mmol kg^{-1} s^{-1}.
[c] Limit of detection = 0.06 nmol/g min.

2.3. Physical characterization of pods

Weight and length of a minimum of 20 pods were measured before and after each blanching treatment to determine the average weight loss and shrinkage. Processed samples were also classified as good- or poor- quality based on their external appearance (Ramaswamy & Fakhouri, 1998).

Pod texture was determined according to a modification of the method of Krebbers, Matser, Koets and Van Den Berg (2002), using a texture analyzer (Stable Micro Systems TA-XT2i, Godalming, UK) with a Warner-Bratzler blade (downward motion 1 mm/s). Firmness was quantified as the maximum force to cut the pods into 2 longitudinal halves. Fifteen pods were taken for each sample and the results averaged.

Color of samples (16 pods each) was evaluated by spectrophotometry (Perkin-Elmer Lambda 5, Palo Alto, U.S.A.) and expressed in terms of CIE values for lightness (L^*), redness (a^*), and yellowness (b^*) (Tijskens, Schijvens, & Biekman, 2001). A standard CIE source C illuminant and an observer angle of 2° were used. Additionally, other related-color parameters such as the hue angle (H^*) and total color difference (ΔE^*) were obtained.

Hue is the attribute of color perception (red, yellow, green), particularly interesting because of its close correlation with the chlorophyll content (Lau, Tang, & Swanson, 2000) and therefore with the color of green vegetables (Hayakawa & Timbers, 1977). The color hue is defined as:

$$H* = \tan^{-1}(b*/a*). \quad (1)$$

Total color difference is an index of the overall color change in relation to a reference standard (Maskan, 2001). By using the corresponding values of the fresh unblanched pods as reference (subscript 0), it is calculated as:

$$\Delta E* = \left[(L*-L_0*)^2 + (a*-a_0*)^2 + (b*-b_0*)^2\right]^{1/2}. \quad (2)$$

2.4. Enzyme assays

The enzyme extraction procedure was a modification of the method proposed by Lambais, Ríos-Ruiz and Andrade (2003). Each batch of treated pods was homogenized in a domestic blender for 2 min. About 1 g of this puree (exactly weighted) was mixed with 10 mL of phosphate buffer solution (0.100 mol/L). This mixture was stirred for 10 min, filtered (Whatman 541), and finally centrifuged at 4500 rpm for 10 min. The supernatant was stored at −20 °C until further analysis. All enzyme assays were performed in triplicate in a final volume of 3 mL, and enzyme activities determined spectrophotometrically (Thermo Electron Heλios-γ, Cambridge, UK).

L-ascorbate peroxidase (APX) activity was assayed as described by Nakano and Asada (1981) by recording the decrease in ascorbate