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Short communication

Impact of temperature on lethality of kiwifruit puree pasteurization by thermal and microwave processing

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ABSTRACT

The use of pasteurization units (PU) as a measure of the lethal effect of processes was proposed with the aim of comparing conventional and novel thermal technologies. Kiwifruit puree was subjected to microwave (1000 and 900 W) and conventional (97 °C) heating. Processing conditions of the treatments were chosen to simulate a pasteurization treatment. The temperature profiles of the samples during processing were recorded at different positions. The coldest and hottest spots of the product were identified and the associated PU numbers were calculated. A significantly ($p < 0.05$) higher thermal load was necessary in order to stabilize the kiwifruit puree under conventional (19.27 min) than microwave heating mode (0.003–8 min) at any of the conditions studied. The higher effectiveness of microwave heating could be attributed to non-thermal effects associated with this technology.

1. Introduction

Microwave heating (MW) appears to be a promising novel technology for food preservation (Vadivambal & Jayas, 2010). During recent decades, many studies have been carried out on the evaluation of MW benefits with respect to conventional heat treatments. Its suitability for pasteurization, sterilization, and dehydration processes as well as its capacity of producing safe and better quality products has been widely demonstrated (Igual, García-Martínez, Camacho, & Martínez-Navarrete, 2010). Although MW could potentially replace conventional heat processes for some specific applications (Awuah, Ramaswamy, & Economides, 2007), there are still problems that are inherent in this technology, such as non-uniform product temperature distribution (Salazar-González, San Martín-González, López-Malo, & Sosa-Morales, 2012), and that contribute to delaying the exploitation of MW to its fullest potential in the food industry.

On the other hand, improper comparison between treatments because of inadequate control of processing parameters such as sample temperature exposure, roughly selected exposure periods or poor kinetic data accommodation may be generating doubts and causing conflicting opinions regarding the superiority of this technology against conventional heat treatments. Some authors have proposed different ways of comparing microwave and conventional treatments: (i) to select processing conditions to get equal heating rates (°C/min) (Fujikawa, Ushioda, & Kudo, 1992), (ii) to reach a similar temperature profile in samples under both technologies (Welt, Tong, Rossen, & Lund, 1994), and (iii) to carry out kinetic studies (Matsui, Gut, De Oliveira, & Tadini, 2008). This lack of homogeneity in comparison procedures may result in mistaken interpretations and hinders the contrast of different research works.

In the present study, the concept of accumulated lethality, a parameter traditionally employed to evaluate conventional heat treatments, is proposed as a tool for comparison of conventional and novel thermal technologies. The lethal effect of the process is determined on the basis of the time-temperature history of the product and it is expressed as a numerical value in arbitrary units. The pasteurization unit (PU) was proposed by Shapton, Lovelock, and Laurita-Longo (1971) as a measure of accumulated lethality but more specifically adapted for pasteurization processes.

The objective of the present research work was to assess the suitability of the PU parameter to compare the thermal load of microwave and conventional kiwifruit puree pasteurization treatments.

2. Material and methods

2.1. Sample preparation

Kiwifruit (*Actinidia deliciosa* var. Hayward) was purchased in a local supermarket. Fruit pieces were peeled and triturated in a

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Thermomix (TM 21, Vorwerk, Spain), using the fourth power level for 1 min. The physicochemical characteristics of kiwifruit puree (water content, soluble solids, water activity, and pH) were determined in order to control the fruit which was used as raw material (data not shown).

2.2. Treatments

Processing conditions were chosen based on preliminary experiments to simulate a pasteurization treatment (Benlloch-Tinoco, Pina-Pérez, Martínez-Aguirre, Rodrigo, & Martínez-Navarrete, 2012). The treatments selected inactivated 90% of peroxidase enzyme and reduced more than 5 $\log_{10}$ cycles of the most important pathogenic microorganism (*Listeria monocytogenes*) (data not shown). These data correspond to the global inactivation achieved in the samples. Three replicates of each treatment were run.

2.2.1. Microwave treatment

A household microwave oven (model: 3038 GC, Norm, China) was used to treat the kiwifruit puree. For each treatment, a sample weighing 500 g was tempered to an initial temperature of 25 °C and then heated in the microwave oven in a standard size glass beaker (BKL3-1K0-006O, Labbox, Spain). Two microwave treatments, based on different power–time combinations, were carried out: 1000 W-200 s and 900 W-225 s. The microwave oven was provided with a probe (CR/JP/11/11671, Enelec, Spain) which was connected to a fiber optic thermometer (FOTEMP1-OEM, Enelec, Spain) to continuously record the time-temperature history of the sample during the microwave treatments. Because MW has traditionally been associated with non-uniform heating, the coldest and the hottest spots were identified and the temperature at these points was recorded.

2.2.2. Conventional thermal treatment

The conventional thermal treatment selected consisted in heating the sample at 97 °C for 30 s in a thermostatic water bath (Precisterm, Selecta, Spain). After the kiwifruit was triturated, 20 g of puree was placed in TDT stainless steel tubes (1.3 cm inner diameter and 15 cm length) and closed with a screw stopper. A thermocouple which was connected to a data logger was inserted through the sealed screw top in order to record the time-temperature history of the sample during the treatment. Three replicates were carried out to define an average temperature profile of the process. Previously, the samples were preheated to 25 °C to shorten and standardize the come-up time (150 s).

2.3. Peroxidase enzyme determination

Peroxidase activity (POD) was measured in all the treated samples (microwaved and conventionally heated ones) and also in the non-treated sample, which was used as a control, according to the method proposed by de Ancos, Cano, Hernández and Monreal (1999) with the following modifications. For enzyme extraction, centrifugation was done for 20 min and the filtration step was omitted. Extracts were made in duplicate. Enzyme extract (0.050 mL) was used for the enzyme activity measurement and pH 6.5 was fitted. A solution containing all the components except the enzyme extract, which was replaced by 0.050 mL of sodium phosphate buffer, was used as a blank. One unit of POD activity was defined as the amount of enzyme that caused an increase of one in the absorbance per min ($\mathrm{Abs \cdot min^{-1}\, g^{-1}}$), calculated from the linear part of the curve obtained. The percentage of enzyme inactivation (I) was calculated by using Eq. (1).

$$I = \frac{A_F - A_T}{A_F} \times 100 \quad (1)$$

Where:

A_F: enzyme activity of fresh kiwifruit puree;
A_T: enzyme activity of treated kiwifruit puree.

2.4. L. monocytogenes inactivation study

L. monocytogenes is recommended by the National Advisory Committee on Microbiological Criteria for Foods to be used as a target microorganism for products of similar characteristics. Kiwifruit puree, prepared as described above, was inoculated by adding 1 mL of a *L. monocytogenes* (CECT 4032, Spanish Type Culture Collection) inoculum to give a final concentration of 10^7 CFU/g. Kiwifruit puree was blended for 30 s with the aim of ensuring a homogeneous initial content of the bacterium. After processing, serial decimal dilutions of both treatments and the untreated one were performed in 0.1% (w/v) sterile peptone water (Scharlab Chemie S. A., Barcelona, Spain). The enumeration medium used for viable cells was Tryptic Soy Agar (TSA) (Scharlab Chemie S. A., Barcelona, Spain). The selected dilutions were incubated at 37 °C for 48 h.

2.5. Pasteurization units calculation

The pasteurization units corresponding to the microwave and conventionally treated samples were calculated using Eq. (2) with a reference temperature of 80 °C (Heinz, Toepfl, & Knorr, 2003; Lau & Tang, 2002) and a z-value of 13.62 °C, previously determined for *L. monocytogenes* from inactivation data under thermal processing.

$$PU = \int_0^t 10^{\left(\frac{T(t)-T_{ref}}{z}\right)} dt \quad (2)$$

Where,

t: Treatment time (s);
$T(t)$: Product temperature at each treatment time;
T_{ref}: 80 °C;
z: Temperature sensitivity (°C) for *L. monocytogenes*.

2.6. Statistical analyses

Significant differences were evaluated by means of the corresponding analysis of variance (ANOVA) using Statgraphics Plus 5.1. Differences of $p < 0.05$ were considered to be significant.

3. Results and discussion

Microwave and conventional heating comparison has been the base of many studies dealing with MW process applications, such as those performed by Gentry and Roberts (2005) or Igual et al. (2010). The difficulty of comparing the two technologies lies in the particular way of heating which takes place during MW treatments (Banik, Bandyopadhyay, & Ganguly, 2003). While in conventional heating a holding period is expected, in the case of MW non-isothermal heating takes place exclusively (Matsui et al., 2008). Additionally, fixing the parameters that affect the heating process, such as (i) the heating rate, (ii) the range of temperatures at which the samples are exposed, or (iii) providing appropriate