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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 processes lethal effect was proposed with the aim of comparing both conventional and novel thermal technologies. Kiwifruit puree was subjected to microwave (1000 and 900 W) and conventional (97 ºC) heating. Processing conditions of the treatments were selected to cause a 90% of kiwifruit peroxidase inactivation. The temperature profiles of the samples during processing were registered at different positions. The coldest and hottest spot of the product were identified and the associated PU numbers were calculated. Significantly ($p<0.05$) higher thermal load was necessary in order to inactivate the target level of peroxidase under conventional (19.27 min) than microwave heating mode (0.22-1.8 min) at any of the studied conditions. Higher effectiveness of microwave heating could be attributed to non-thermal effects associated to this technology.

Keywords: Microwaves, thermal treatment, kiwifruit, temperature, accumulated lethality.

1. INTRODUCTION

Microwave heating (MW) appears to be a promising novel technology for food preservation (Cañumir et al., 2002; Vadivambal & Jayas, 2010). During the last decades, many studies have been carried out on the evaluation of MW benefits 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; Huang, Sheng, Yang, & Hu, 2007). Although MW could potentially replace conventional heat processes for some specific applications (Awuah, Ramaswamy, & Economides, 2007), there are still problems that are inherent to this technology, such as non-uniform product temperature distribution (Salazar-González, San Martín-González, López-Malo, & Sosa-Morales, 2012), that contribute 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 the 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 (ºC/min) (Fujikawa, Ushioda, & Kudo, 1992), (ii) to reach similar temperature profile in samples under both technologies (Welt, Tong, Rossen, & Lund, 1994) and (iii) to carry out kinetic studies (Latorre, Bonelli, Rojas, & Gerschenson,

2012; Matsui, Granado, Oliveira, & Tadini, 2008; Tajchakavit, Ramaswamy, & Fustier, 1998). This lack of homogeneity in comparison procedures can result in mistaken interpretations and hiders the contrast of different research works.

In the present study, the concept of accumulated lethality (F_0), parameter traditionally employed to evaluate conventional heat treatments, is proposed as a tool for both conventional and novel thermal technologies comparison. The process lethal effect is determined in base 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 (1970) 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 PU parameter to compare the thermal load of microwave and conventional kiwifruit puree pasteurization treatments.

2. MATHERIAL AND METHODS

2.1. Sample preparation

Kiwifruit (*Actinida deliciosa* var. Hayward) was purchased in a local supermarket. Fruit pieces were peeled and finally triturated in a Thermomix (TM 21, Vorwerk, Spain), using the fourth power level for one minute. 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 log10 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 (3038GC, Norm, China) was used to treat the kiwifruit puree. For each treatment, a sample of 500 g was tempered to an initial temperature of 25º 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: 1000W-200s and 900W-300s. Processing conditions were selected based on preliminary experiments to cause approximately a 90% of peroxidase inactivation (Benlloch-Tinoco, Pina-Pérez, Martínez-Aguirre, Rodrigo, & Martínez-Navarrete, 2012). Three replicates of each treatment were run. The microwave oven was provided with a probe (CR/JP/11/11671, Enelec, Spain) which was connected to a fiberoptical thermometer (FOTEMP1-OEM, Enelec, Spain) to continuously register the time-temperature history of the sample during the microwave treatments. Because MW has been traditionally 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 selected treatment consisted in heating the sample at 97 ºC for 30 s in a thermostatic water bath (Precisterm, Selecta, Spain). After kiwifruit was triturated, 20 g of puree were introduced in TDT stainless steel tubes (13 mm inner diameter and 15 cm length) and closed with a screw stopper. A thermocouple which was connected to a data

logger was introduced through the sealed screwed top in order to register 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, samples were preheated at 25 ºC to shorter and standardise 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 control, according to the method proposed by De Ancos et al. (1999) with the following modifications. For enzymes extraction pH 6.5 was used, centrifugation was done for 20 min and filtration step was avoided. Extracts were made in duplicate. Enzyme extract (0.050 mL) was used for enzymes 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 was defined as the amount of enzyme that caused an increase of one in the absorbance per min ($Abs \cdot min^{-1} \cdot g^{-1}$), calculated from the linear part of the obtained curve. 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. 2L. 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 107 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 ºC for 48 h.

2.5. Pasteurization units calculation

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

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

Where,

t: Treatment time (s);

T(t): Product temperature at each treatment time;

T_{ref}: 80ºC;

z: Temperature sensitivity (ºC) for *Listeria 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 processes applications, such as those performed by Cañumir et al. (2002), Gentry & Roberts (2005) or Igual et al. (2010). The difficulty of comparing both technologies lies in the particular way of heating which takes place during MW treatments (Banik, Bandyopadhyay, & Ganguly, 2003). While in conventional heating holding period is expected, in the case of MW, non-isothermal heating takes exclusively place (Latorre et al., 2012). Additionally, fixing those parameters affecting the heating process such as (i) the heating rate, (ii) the range of temperatures at which the samples are exposed or (iii) providing appropriated sample homogenization, is not usually possible. In this way, products conventionally and microwave treated are not normally subjected to equivalent temperature-time combinations and comparing the effect of both technologies on the product quality may result complicated.

Given the different nature of heating processes taking place under conventional and microwave modes, the temperature control should not be limited to the initial and the final point of the process, but the whole temperature history of the product should be taken into account. In this context, the PU parameter offers the possibility of evaluating the complete thermal load of the heating processes at any reference temperature, as if it had taken place under isothermal conditions. This implies that the product is considered

175 to instantaneously reach the reference temperature (Matsui et al., 2008), so the effect of
176 processing factors that could be promoting differences in the nature of the heat
177 transference such as (i) product characteristics including consistency, solid/liquid ratio
178 and thermophysical properties, (ii) sample quantity and (iii) container type, size and
179 shape (Augusto & Cristianini, 2011; Awuah et al., 2007), is avoided.

180 The concept of accumulated lethality has been previously used in relation to
181 microwaves in order to validate the lethal effect of a formerly established preserving
182 treatment (Chen, Campanella, & Peleg, 2011; Wang, Wig, Tang, & Hallberg, 2003). It
183 has also been employed as a tool for assessing the effect of a conventional and a
184 combined microwave-conventional pasteurization process on the nutritional and sensory
185 quality of asparagus by calculating C-value (Lau & Tang, 2002). However, up to date,
186 PU has still not been used with the aim of evaluating the thermal load of various
187 conventional and novel heating processes to perform comparison.

188 In the present study the temperature profiles of various kiwifruit puree samples
189 subjected to some microwave and conventional thermal treatments were registered in
190 order to compare the different processes lethal effects (Figure 1). Although the
191 conventionally treated and the microwaved samples showed the same level of POD
192 inactivation (90%) and L. monocytogenes reduction (>5 log10-cycles), noticeable
193 differences in the temperature-time profiles can be observed in Fig. 1. The thermal load
194 associated to each treatment was calculated through the PU parameter. Mean value (and
195 standard deviation in brackets) of PU numbers obtained for all the assayed treatments
196 are presented in Table 1. As expected, substantial differences were found in the thermal
197 load received by the product at the two locations studied during the microwave
198 treatments. The PU obtained at the hottest spot was considerably higher than the PU
199 obtained at the coldest spot. On the other hand, the conventional heating mode required

200 a significantly ($p < 0.05$) higher thermal load to achieve the pre-set level of POD
201 inactivation in the kiwifruit puree than any of the microwave treatments studied,
202 irrespective of whether the comparison was carried out at the coldest or hottest spot of
203 the sample. When the microwave treatments were compared, 900W-225 s was the one
204 showing the highest and lowest thermal load at the hottest and coldest spot,
205 respectively. However, significant differences ($p < 0.05$) were only observed in relation
206 with the hottest spot. The greater effectiveness of MW with respect to conventional
207 heating treatments for food stabilization has been widely reported by various authors,
208 such as Matsui et al. (2008) and Soysal and Söylemez (2005). Although differences
209 observed in MW and conventional heating processes have traditionally been attributed
210 to the faster heating rates ofMW (El-Abassy, Donfack, & Materny, 2010), in our case
211 this premise cannot be accepted to explain the differences observed, because the PU
212 data were calculated as if the treatments had taken place under isothermal conditions.
213 Consequently, they might indicate the possibility of some contributory non-thermal
214 effects associated with MW. Although other authors have reported similar findings
215 (Banik et al., 2003), in-depth research work on this area is considered necessary.
216
217 **4. CONCLUSIONS**
218 The pasteurization unit seem to be an adequate parameter to evaluate the thermal
219 load associated to conventional and microwave heating processes. This parameter can
220 be taken as a common base to compare the effect of different heating technologies on
221 the products quality and stability. Microwave heating required lower thermal load than
222 conventional heating to pasteurize the product any of the power levels studied, which
223 might be attributed to some contributory non-thermal effects associated with this
224 technology.

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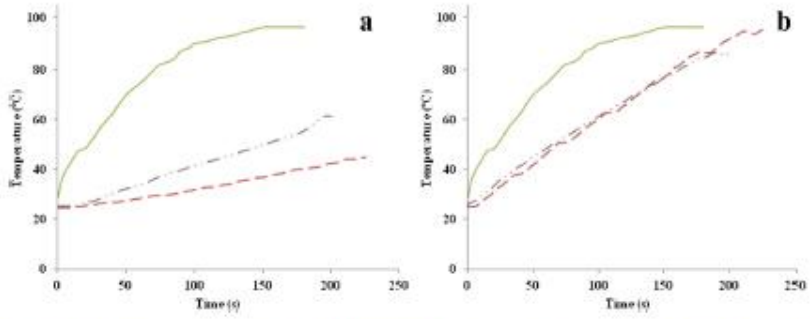

Fig. 1. Temperature profile of kiwifruit puree subjected to conventional thermal (——) and microwave (1000 W, — · — and 900 W, — — —) processing at the coldest spot (a) and the hottest spot (b) of the product.

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Table 1
Mean values and standard deviation (in brackets) of pasteurization units (PU) calculated at the coldest and the hottest spot of the kiwifruit puree under conventional and microwave (1000 and 900 W) heating. The same superscript letters in columns (x, y for coldest spot data and a, b, c for the hottest spot data) indicate homogeneous groups established by the ANOVA ($p < 0.05$) when the different treatments are compared.

Treatment	PU (min)	
	Coldest spot	Hottest spot
Conventional heating	19.27 (0.13)^{yc}	
Microwave heating		
1000 W-200 s	0.046 (0.007)^{x}	1.79 (0.02)^{a}
900 W-225 s	0.0027 (0.0014)^{x}	7.9 (1.4)^{b}

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