Research Note

Pulsed Electric Fields Versus Thermal Treatment: Equivalent Processes To Obtain Equally Acceptable Citrus Juices

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ABSTRACT

Pulsed electric field treatment has been claimed to produce more acceptable chilled citrus juices than those obtained by conventional thermal treatment. The pectin methylesterase activity and the acceptability of nine juices obtained from Clementine mandarins, Valencia oranges, and Ortanique fruits (hybrid of mandarin and orange), untreated, pasteurized (85°C for 10 s), and treated by pulsed electric fields (25 kV/cm for 330 μs), were evaluated. The treatments, selected to reach a similar level of pectin methylesterase inactivation, produced juices that did not differ in acceptability from each other for the three varieties and in all cases were less acceptable than the untreated juice.

Conventional processes to preserve citrus juices involve the use of heat treatments to inactivate microorganisms and enzymes. Pectin methylesterases (PME), which produce cloud loss, are more resistant to heat than common spoilage microorganisms (4). Thus, the intensity of the treatment aims at reaching sufficient enzyme inactivation (10).

Pasteurization at 90°C for 60 s is the conventional method used in the citrus industries to inactivate PME (2). However, this treatment also results in thermal damage, thus reducing the freshness of juice flavor (6). Irwe and Olsson (3) considered a reduction of PME activity below 10% of its initial value acceptable for commercial chilled orange juices. In a previous article (9), we concluded that by a mild pasteurization at 85°C for 10 s, this inactivation level is achieved with minimum loss of fresh taste.

Pulsed electric fields (PEFs) are an alternative technology to thermal pasteurization. It has been reported that they produce more acceptable citrus juices than those obtained by conventional thermal treatment (11). The authors concluded that by a PEF treatment of 35 kV/cm for 59 μs, the residual level of PME activity in orange juice is about 12% and that obtained juices are more acceptable than samples pasteurized at 94.6°C for 30 s. However, these treatments are probably not comparable since by the latter a complete PME inactivation is obtained (9) but not by the PEF treatment. Total inactivation is not necessary for short life, high quality products (3) and, moreover, the thermal conditions needed for a complete inactivation lead to a loss of freshness (9).

For a proper comparison of the effects on acceptability of PEF and heat treatment, both processes must produce similar levels of PME inactivation. In our work, a PEF process (25 kV/cm for 330 μs) and a mild pasteurization at 85°C for 10 s, both leading to comparable levels of PME inactivation, have been applied to juices from mandarins, oranges, and a hybrid of the two species. The resulting samples were evaluated for acceptability.

MATERIALS AND METHODS

Fruits. Clementine mandarins (Citrus reticulata cv. Nules), Ortanique fruits (hybrid of Citrus reticulata × Citrus sinensis), and Valencia oranges (Citrus sinensis) were harvested on 27 February, 5 May, and 25 May 2005, respectively, in an orchard located in Llíria (Valencia) and used immediately for juice preparation.

Extraction and finishing. The fruits were washed by immersion in tap water, drained, and squeezed in an industrial extractor with finger cups (Exzel, Luzzysa, El Puig, Valencia, Spain). According to the specific characteristics of our PEF pilot equipment, it was necessary to sieve all the raw juice, firstly in a screw finisher (holes 0.5 mm diameter) and again through a sieve of 0.297 mm.

Fresh juice. A part of the juice sieved was immediately bottled in 1-liter glass jars.

Pasteurized juice. Another part was thermally treated at 85°C for 10 s (holding time) and cooled at 7°C in a plate heat exchanger (APV Ibérica S.A., Madrid). The juice was aseptically packed in 1-liter glass jars previously sterilized by steam.

PEF juice. The remaining sieved juice was treated in an OSU-4D bench-scale continuous PEF equipment (designated at Ohio State University) following the operating conditions proposed by Rodrigo et al. (7) with a minor modification. A set of six cofield flow, tubular PEF treatment chambers, with a diameter of 0.23 cm and gap distance of 0.293 cm, were serially connected. Two cooling coils were placed before and after each pair of chambers and submerged into a water bath for temperature control. The

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temperature was monitored by type T thermocouples fixed to the
coil and connected to a data acquisition system indicator. Pulse
waveform, voltage, and intensity of PEF treatment were monitored
by a digital oscilloscope (Tektronix TDS 210, Tektronic, Inc.,
Oreg.). The flow rate was set at 60 ml/min and a square-wave
bipolar pulse duration of 2 μs was selected. Treatment conditions
were 25 kV/cm for 330 μs and a maximum temperature of 72°C
± 1°C (about 1.5 s, time needed for the juice to reach the cooling
bath). Samples were collected in sterile 1-liter glass jars. The mi-
nor modification consisted in an increase of temperature from 63
to 72°C to reach an inactivation level of PME near 90%.

**Brix and acidity.** Total soluble solids were measured as
*Brix with a digital refractometer (Pal-1, Atago Co., Ltd., Tokyo,
Japan). Total titratable acidity was assessed by titration with 0.1
N NaOH and expressed as % citric acid.

**PME activity.** PME activity was determined according to a
previously published method (1), based on a modification of the
conventional procedure published by Rouse and Atkins (8). The
PME activity of each juice was analyzed in triplicate.

**Sensory analysis.** Simple ranking tests were carried out the
same day of sample preparation of each variety and consisted in
ordering the three samples (fresh, pasteurized, and PEF) by ac-
ceptability. About 43 to 54 nontrained persons belonging to the
staff of our institute participated in the tests that were conducted
in a standardized room equipped with separate taste booths. Un-
covered transparent glasses of 100-ml capacity were used to serve
samples whereas other assessors preferred PEF samples, thus
compensating rank sums. To clarify this point a triangle test
was performed with both samples of Clementine juice.

<table>
<thead>
<tr>
<th>TABLE 1.</th>
<th>Characteristics and pectin methylesterase (PME) activity of the juices (fresh, pasteurized, and PEF treated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit characteristics</td>
<td>PME activity (nkat) (relative activity, %)</td>
</tr>
<tr>
<td></td>
<td>Brix</td>
</tr>
<tr>
<td>Clementine</td>
<td>12.0</td>
</tr>
<tr>
<td>Ortanique</td>
<td>12.7</td>
</tr>
<tr>
<td>Valencia late</td>
<td>10.6</td>
</tr>
</tbody>
</table>

* Average value (calculated from three replicates) ± standard deviation.

**RESULTS AND DISCUSSION**

Table 1 shows solid contents and *Brix to acid ratios
of the studied samples. PME activity is also shown in the
table as an absolute value and as a percentage of the initial
activity in fresh juice. The intensity of the thermal treatment
was designed to inactivate the enzymes of Ortanique, which
was the variety showing maximum thermoresistance ac-
cording to previously published results (9). The conditions
of the PEF treatment were adjusted in an attempt to reach
comparable levels of inactivation to those achieved by ther-
mal treatment but, as Table 1 shows, the residual activity
was slightly higher by the PEF treatment for all varieties.
A two-way (varieties and treatments) analysis of variance
applied to relative activities in Table 1 (6 data points)
showed significant differences at a probability of 0.05 be-
tween treatments (Table 2). Nevertheless, the remaining
activity can be considered acceptable with the possible ex-
ception of PEF Ortanique Juice.

Although no microbial analyses were performed, we
may assume that both treatments produced sufficient mi-
Crobiological inactivation. On the one hand, it is a known fact
that citrus juices flora is destroyed by heat conditions that
assure enough enzyme inactivation (4). On the other hand,
studies carried out with blends of orange and carrot juices
(7) showed that a treatment at 25 kV/cm for 340 μs com-
bined with moderate temperature (63°C) produced 81.4% of
PME inactivation, 3.7 decimal reductions of fungi and
yeasts, and 2.4 decimal reductions of total flora.

Table 3 summarizes the results of the simple ranking
tests comparing the acceptability of the samples of each
variety. In all cases, fresh juice was considered significantly
(P < 0.05) more acceptable (ranked first by most assessors,
lowest rank sums) than pasteurized or PEF juices, which
did not significantly differ from each other in any case.

It could be argued that pasteurized and PEF juices re-
ally differed in acceptability and that the assessors detected
the differences but some of them preferred pasteurized sam-
ple whereas other assessors preferred PEF samples, thus
compensating rank sums. To clarify this point a triangle test
was performed with both samples of Clementine juice.

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| TABLE 2. Two-way analysis of variance of relative PME inactivation* |
|----------------------|------------------|-----------------|------|
| Source of variability | Sum of squares | Degrees of freedom | Mean squares | F-values |
| Varieties | 0.00203 | 2 | 0.00102 | 6.46 | b |
| Treatments | 0.00405 | 1 | 0.00405 | 25.70 | c |
| Residual | 0.00032 | 2 | 0.00016 | | |

* Arcsin transformation was applied.

b Critical value (0.05) = 19.
c Critical value (0.05) = 18.5.
TABLE 3. Sensory results from simple ranking test comparing the acceptability of fresh, pasteurized and PEF juices

<table>
<thead>
<tr>
<th>Samples</th>
<th>Clementine (43 assessors)</th>
<th>Ortanique (54 assessors)</th>
<th>Valencia (51 assessors)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>68</td>
<td>87</td>
<td>80</td>
</tr>
<tr>
<td>Pasteurized</td>
<td>92</td>
<td>118</td>
<td>116</td>
</tr>
<tr>
<td>PEF</td>
<td>98</td>
<td>119</td>
<td>110</td>
</tr>
</tbody>
</table>

Minimum significant difference in rank sums (probability 0.05) 18 20 20

From 24 assessors, only 7 correctly identified the odd sample, which indicated that no significant differences can be concluded between treatments since the critical number of correct answers at a level of 0.05 is 13.

PEFs (25 kV/cm for 330 μs) and pasteurization at 85°C for 10 s produced chilled juices of Clementine, Valencia, and Ortanique that did not differ in acceptability even when the heat treatment was more energetic, as this treatment resulted in slightly but significantly more PME inactivation.

ACKNOWLEDGMENTS

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REFERENCES