MICROWAVE PROCESSING IN ORANGE JAM MANUFACTURING: EFFECT ON COLOR DEGRADATION KINETICS

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Abstract: Improvement of color, as a quality attribute of jam products, has been made possible by the increase in knowledge of kinetic of color change. Effect of microwave processing (MW) at 700 W on the color kinetics of orange jam was compared to conventional heating (CH) method. L, a, b parameters were used to estimate the extent of color loss. Zero- and First-order kinetic models were applied to describe color change.

Both models were found to describe the experimental (L,a,b) kinetics adequately. The Hunter parameters kinetics were more influenced by the MW process but no significant difference was found in the final product.

Keywords: orange, jam, color, microwave, kinetics

INTRODUCTION

In jam processing, concentration step is a unit operation of critical importance as it determines the quality of the final product such as flavour, color, aroma, appearance and mouth feel (Jiao Cassano, & Drioli, 2004). Traditional jam manufacturing methods require concentration by heat treatments, primarily intended to inactivate enzymes, deteriorate microorganisms and reduce water activity by dehydration. However, this process leads to color degradation and loss of most volatile compounds with a consequent remarkable qualitative decline (Cassano et al., 2004; Jiao et al., 2004; Alibas et al., 2005). To reduce these problems, faster and more effective evaporation processes, such as microwave application may be considered for jam manufacturing. Zhang et al. (2006) have reviewed recent research on microwave assisted drying, focusing primarily on fruits and vegetables. These authors suggested that there is still a lack of theoretical analysis, modelling and simulation in the area of microwave-related food processes to optimize final quality. With regard to color, color is a key property governing initial consumer acceptability of any food. Optimizing microwave thermal processing to improve the product color requires data on color degradation kinetics (k values). Zero-order (equation 1) and first-order (equation 2) kinetic models have been used to evaluate the appearance of browning in fruits and fruit products (Maskan et al., 2006):

\[
\begin{align*}
\text{Zero order: } & \ C = C_0 + k_0 \cdot t \\
\text{First order: } & \ C = C_0 \exp (k_1 \cdot t)
\end{align*}
\]

Orange juice is rich in vitamin C, folic acid, potassium, and is an excellent source of bio-available antioxidant, photochemical. It significantly improves blood lipid profiles in people affected with hypercholesterolemia. Nutritionists recommend preserving these compounds during fruit juice processing. New orange processing methods can be of a great interest.

No previous data have been found to describe the influence of application of microwave energy on orange jam quality. The present work was undertaken to study the effect of conventional heating (CH) and microwave (MW) processes on color quality of orange jams, as a function of the initial sugar content which has been varied in order to respond to current dietary requirements.

MATERIALS AND METHODS

Materials

Fresh orange of the cultivar Valencia, pectin and sugar were purchased from a local market in Tunis.

Jam preparation procedures

Fresh orange slices were mixed with different sugar concentrations (30%, 40% and 50%) and 0.5% pectin using a domestic mixer.

Conventional heating method

A 500 ml of the previous mixture was concentrated and stirred continuously until reaching 60-65 °Brix using an electric heater (VELP Scientifica, Italy) at 100°C open to atmosphere.

Microwave jams processing

A programmable domestic microwave oven (Samsung 580, CHINA) was used with an output of 700 W. A 500 ml of the mixture was put on the
center of the microwave cavity turn table. Processing was stopped when TSSC reached 60-65°Brix.

**Analysis**

For both processes, samples were taken for measurement of Brix and color periodically. TSSC measurements were carried out using a refractometer at 20 °C (Zeiss, ATAGO model NAR-3T refractometer, Japan). Color parameters were determined using a tristimulus colorimeter (Minolta Chroma Meter CR300, Japan). The L, a, and b refer to color values at various times during concentration process. Statistical Analysis of variance (ANOVA), with a confidence level of 95% (p<0.05), using SAS Software version 1997 was applied to evaluate the differences between mean values among the different treatments. Analyses were run in triplicate.

**RESULTS AND DISCUSSIONS**

**Change in total soluble solid concentration during evaporation processes**

Brix kinetics, during jam processing, under (Fig. 1) was carried out in order to optimize the cooking time after which samples will reach a final jam TSSC of 60-65 °Brix.

![Fig. 1: Brix kinetics during the orange jam concentration by conventional heating (CH) and microwave (MW).](image)

A non-linear regression analysis results on experimental data showed that zero- and first-order reaction kinetics equations (EQ. 1 and EQ. 2) allow a good prediction of the TSSC change (R² > 0.90). The evaporation rate constant values k₀ ranged from 0.003 to 0.023 and k₁ from 0.175 to 1.604 for zero order and first order models respectively. The rate of brix change for MW samples was more than 9 times greater than CH samples (fig. 1). MW induces rapid heating and, hence, water evaporation is more rapid (Igual et al., 2010). In fact, MW interacts directly with the polar water molecules to generate heat. Table 1 shows that using MW reduces significantly jam processing time (p<0.05). Evaporation occurs inside the product, increasing the internal pressure and concentration gradients, ending up with more effective water diffusion (Sumnu et al., 2005). Also MW uses higher quality (and more expensive) electrical energy converted into MW radiation by magnetrons rather than the thermal energy (Zhang et al., 2006).

**Table 1: Physico-chemical characteristics of orange jams produced by microwave (MW) and conventional heating (CH).**

<table>
<thead>
<tr>
<th>Initial sugar concentration</th>
<th>Final °Brix</th>
<th>Process time (min)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>30%</td>
<td>62.5</td>
<td>63</td>
<td>3.54</td>
</tr>
<tr>
<td>40%</td>
<td>63</td>
<td>63</td>
<td>18</td>
</tr>
<tr>
<td>50%</td>
<td>63.5</td>
<td>64</td>
<td>12</td>
</tr>
</tbody>
</table>

**Color degradation kinetics**

To minimize the variability between different raw samples (before concentration processes), color changes were assessed using L′ (L/L0), A′(a/a₀) and B’(b/b₀) (figure 2a, b, and c).

The L′ and B’ parameters decreased in both CH and MW treatments for the three sugar concentrations (30%, 40% and 50%) jam products. Hence, samples, after evaporation process, were darker and less yellow. A’ values increased right at the beginning of the concentration treatment, meaning that the samples were redder (Fig. 2b). For both treatments, when compared with raw samples, the concentration process led to great color differences. Many reactions can take place during thermal processing that affect product color: pigment degradation, especially carotenoids anthocyanin and chlorophyll, browning reactions such as the Maillard reaction, enzymatic browning and oxidation of ascorbic acid (Fratianni et al., 2010).

The L, A, B parameters tended to change faster during MW process compared to CH process. For 30% initial sugar concentration, an L-value of about 45 was reached after 20 min for MW and about 80 min for CH (fig. 2a). Therefore, MW at power 700 W would give a color degradation rate 2 times faster. However, no significant differences (P > 0.05) were detected between both processes in terms of final L’, A’, and B’. Hence, 700W MW application preserves the same color parameters than CH in a shorter time.

Experimental color parameters data L’, A’ and B’ were fitted to different kinetic models (equations 1 and 2). Regardless of the processing method, both zero- and first-order reaction kinetic models can be used adequately to predict L’ and A’ and B’ values (R²: 0.89 to 0.99). In all cases, the zero-order model kinetic constant k₀ ranging from 0.001 to 0.144 were higher than those of the first-order model k₁ (from 0.001 to 0.079).

The rate of variation in a-value (sharp increase, fig. 2b) and in b-value (sharp decrease, fig. 2c) using MW was very fast during the first 20 min of the process. This is probably due to the high temperatures generated by MW inside the samples.
A similar behavior was observed by Barreiro et al. (1997) which stated that the presence of heat sensitive reactions in the curve first phase involves the degradation of thermolabile pigments, which in turn resulted in dark compounds formation reducing luminosity (L), while in the second phase more thermostable pigments were involved.

REFERENCES


