EFFECT OF CONTINUOUS-FLOW MICROWAVE PASTEURIZATION ON PROFILE OF VOLATILE COMPOUNDS IN CLOUDY APPLE JUICE

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ABSTRACT – This work aims to evaluate the impact of continuous-flow microwave-assisted pasteurization on volatile compounds of cloudy apple juice compared to conventional thermal processing. Twelve experimental conditions were tested using a pilot scale unit. A total of 57 volatile compounds was identified using gas chromatography-mass spectrometry (CG-MS). The main volatile compounds were esters and alcohols followed by aldehydes, hydrocarbons, ethers, furan and ketone. In general, the volatile profiles of microwave pasteurized samples were more similar to non-pasteurized apple juice when compared to conventionally pasteurized samples. The difference can be attributed to the shorter exposure to high temperatures during microwave heating.

1. INTRODUCTION

Microwave heating has various applications in food processing, for example, in the pasteurization and sterilization of liquid foods. Continuous-flow microwave heating system replacing the conventional heat exchanger offers some advantages for pasteurization process such as fast volumetric heating, lower equipment surface temperature and higher energy efficiency (Chandrasekaran et al., 2013). Today, consumers claim for minimally processed foods with high content of bioactive compounds. However, conventional thermal processing reduces the concentration of bioactive compounds and leads to loss of sensory properties (Rawson et al., 2011). The aim of this study was to evaluate the volatile compounds of 12 samples of pasteurized cloudy apple juice after microwave and conventional processing. An understanding of the composition of volatiles may help in the selection of optimum operational conditions that improve the product quality.

2. MATERIAL AND METHODS

2.1. Cloudy Apple Juice Processing
Freshly squeezed apple juice (70 L) was processed in a continuous-flow microwave pasteurizer Lab25-UHT/HTST EHVH (MicroThermics, Raleigh, USA), as detailed by Siguemoto et al. (2018a) (Figure 1). To evaluate the effect of processing on the profile of volatile compounds, twelve conditions were tested (Table 1, C = conventional, M = microwave) based on commercial pasteurization of apple juice (Sinha, 2012) and enzymatic inactivation kinetics (Siguemoto et al., 2018b).

![Figure 1 – Schematic representation of the pilot-scale microwave-assisted pasteurization unit.](image)

**2.2. Analysis of Volatile Compounds**

Profile of volatile compounds was determined using a CG-MS Hewlett-Packard 6890 (Agilent Technologies, Santa Clara, USA), according to Gomes et al. (2016). The volatile compounds identification was based on mass spectra matching with spectra data of MassBank of North America (MoNA, USA) and on comparison of retention indexes of authentic external standards or with NIST library (NIST98, Gaithersburg, USA).

Principal Component Analysis (PCA) was made with MetaboAnalyst 3.0 (Xia and Wishart, 2016) to visualize the relationship between apple juice treatments and volatile profile.

**2.3. Determination of Equivalent Processing Time**

The time-temperature history of the juice assuming plug-flow, \( T(t) \), was determined based on the model presented and validated by Siguemoto et al. (2018a). This model was based on overall heat transfer coefficients at the heat exchangers and holding tube and on the mean residence times of the steps of the process (Figure 1).

The equivalent processing times \( (t_e) \) at \( T_{ref} = 80 \, ^\circ\text{C} \) were calculated with Eq. (1) by integrating the lethality function based first order kinetics and using the time-temperature profile with parameter \( z = 25 \, ^\circ\text{C} \), previously established from nutrient degradation (Toledo, 1999).

\[
t_e = \int_0^t \text{alog}\left(\frac{T(t) - T_{ref}}{z}\right) dt
\]  

(1)
3. RESULTS AND DISCUSSION

Figure 2 presents typical time-temperature histories for conventional and microwave-assisted pasteurization of cloudy apple juice. It can be seen that the time needed to reach the desired processing temperature is very short with microwave heating.

![Figure 2 – Time-temperature histories of cloudy apple juice at conditions C3 and M3, showing measured temperatures (▲) and model prediction (−).](image)

Flow rates ($Q$) and process temperatures ($T$) for the two heating modes and equivalent time process ($t_e$) are shown in Table 1. Each pair of conditions has similar holding times; however, $t_e$ for the microwave conditions were lower due to fast increase in temperature.

| Id. | $Q$ (L/min) | $T$ (°C) | $t_e$ (s) | Id. | $Q$ (L/min) | $T$ (°C) | $t_e$ (s) |
|-----|-------------|---------|----------|-----|-------------|---------|----------|
| C1  | 0.5         | 70      | 35       | M1  | 0.4         | 70      | 15       |
| C2  | 0.9         | 70      | 16       | M2  | 0.8         | 70      | 8        |
| C3  | 0.5         | 80      | 93       | M3  | 0.4         | 80      | 37       |
| C4  | 0.9         | 80      | 41       | M4  | 0.8         | 80      | 19       |
| C5  | 0.5         | 90      | 242      | M5  | 0.4         | 90      | 89       |
| C6  | 0.9         | 90      | 106      | M6  | 0.8         | 90      | 47       |

A total of 57 volatile compounds was identified in samples of cloudy apple juice, including 27 esters, 16 alcohols, 4 aldehydes, 6 hydrocarbons, 2 ethers, 1 ketone and 1 furan. Esters are the main of volatile compounds found in pasteurized apple juices, as there were 15 ethyl esters, 4 acetate esters and 8 other esters. The ethyl esters have been described as fruity fragrance, while acetate esters give a fruity and ethereal odor.

Based on PCA (Figure 3A), there is a separation in two groups with different PC1 (NP+M and C), showing different effects of heating mode (microwave and conventional) on the volatile composition. The heatmap analysis (Figure 3B) shows the samples treated with microwave (M) are closer to non-pasteurized (NP), indicating a similarity of volatile compounds.
4. CONCLUSION

PCA showed that the volatile profile of the microwave pasteurized apple juice was more similar to the non-pasteurized juice, in comparison with the conventionally pasteurized juice. This difference can be attributed to the shorter exposure to high temperature during microwave heating, leading to a smaller degree of over-processing.

5. FUNDING

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