Continuous microwave heating effects on quality of carrot and tomato smoothie

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Abstract

The effect of conventional and microwave pasteurization on the lycopene and β-carotene content and on the physicochemical quality attributes (TSS, pH, TA and color) of pasteurized orange smoothie were evaluated. The smoothie was elaborated with tomato, carrot, pumpkin, lemon juice, mineral water and marine salt. The conventional pasteurization (CP) was made by mean of a semi-industrial thermomix, while for microwave pasteurization (MWP) an innovative semi-industrial continuous microwave oven was used. After both pasteurization methods no significant changes in TSS, pH and TA were found while the carotenoids content was enhanced. MWP provided the highest lycopene and β-carotene content, showing MW equipment as a tool to pasteurize and improve the bioavailability of carotenoids of the smoothie.

Keywords: Pasteurization; quality attributes; carotenoids.

1. Introduction

Fruits and vegetables contain large amounts of antioxidants interesting for the human diet, including carotenoids, vitamins, flavonoids, other phenolic compounds, glutathione, and endogenous metabolites [1, 2]. Smoothies are an increasingly popular way of consuming fruits and vegetables. Traditionally, smoothies consist of a number of ingredients including fruit, vegetables, fruit juice and ice. Smoothies are often thermally processed which has been shown to affect the carotenoids and color of foods [3]. Color is the most important quality attributes of juice and smoothie that influence the consumer's choice and a number of studies have shown that thermal processing has a marked impact on the color of products [4]. Regarding food quality and safety some of these changes are undesirable and must be minimized. Nowadays, the purpose of thermal processing is to extend the shelf-life of products without lowering the quality attributes and safety. On the other hand an emergent method for pasteurization of the smoothies and juices using the energy of microwaves (MW) has been developed. This technique might be useful in retaining the nutritional quality of foods after processing, especially in these such as smoothies which contain a high quantity of carotenoids. The MW processing offers many advantages over conventional techniques being particularly useful for homogeneous products, such as smoothies. It has been shown that food processed in this way maintains its original freshness, flavor, and taste, while color changes are minimal [3]. Despite alternations to the structure of high-molecular-weight molecules such as proteins and carbohydrates, MW is unable to affect smaller molecules associated with the sensory, nutritional and health promoting properties such as volatile compounds, pigments, and vitamins.

The aim of this study was to investigate the changes in carotenoids and color in orange smoothies heat treated under conventional and MW pasteurization.

2. Materials and Methods

2.1. Sample preparation

After several preliminary tests the smoothie has been designed and prepared including tomato (126 g), carrot (61 g), pumpkin (29 g), lemon juice (4 mL, to reach a pH of 4.5), mineral water (50 mL) and 0.3 g marine salt. The ingredients were blended for 3 min in a semi- industrial thermomix (Vorwerk elektrowerke, Model TM 31-1, France) with speed 8. Fresh control smoothies were chilled (5°C) immediately after blending.

2.2 Treatments

MW pasteurization (MWP): An innovative semi-industrial prototype of continuous MW oven (MWO, Sairem Ibérica S.L. SI-MAQ0101, Barcelona, Spain) has been installed and tuned to carry out the current experiments. The continuous-flow system of the MWO includes a feed belt with a move back and forth process, an optimized heating chamber, high efficient energy economizing filters, a computer interface and a fiber optic slip ring for online temperature measurements. Based on our preliminary studies several appropriate temperature/time combinations of MW treatment were selected. To obtain MW pasteurized sample, 600 mL of sterile smoothie were heated in glass containers. The glasses were placed in the feed system of the MWO and treated on high power/short time (1600 and 3600 W for 206 and 93 s) and low power/long time (210 and 260 W for 646 and 608 s) conditions.

Conventional pasteurization (CP): Samples were heated in the semi-industrial thermomix above described at 90°C for 35 s. For each cycle about 600 mL of each smoothie were prepared. After both kind of pasteurization, the samples were rapidly cooled down (0°C) into a water-ice bath, packaged into the plastic tubes and then stored at 5ºC to be freshly analyzed. Three treatment series were performed for each heating method. Finally, samples were evaluated for each treatment.

2.3. Chemical and Physical Analysis

The analysis were carried out before (control) and after MW treatment. For each treatment and evaluation period, three replicates were analyzed.

2.3.1. Color measurement

The color of samples was determined with a colorimeter (Minolta CR-300, Ramsey, NJ, USA) in triplicate. The equipment was calibrated using a standard white reflector plate. Readings were obtained using the standard CIE (Committee International d'Eclairage) L* (lightness), a* (redness) and b* (yellowness). The results were expressed as L* and hue angle ($h° = \tan^{-1}(b^*/a^*)$).

2.3.2. Measurement of soluble solids content (SSC), pH and total titratable acidity (TA)

Soluble solids content of smoothies were determined using a digital refractometer (Atago, Tokyo, Japan) and expressed as °Brix. Samples pH was measured with a pH meter (Crison 2001 pH meter, Instruments SA, Barcelona, Spain) calibrated with phosphate buffers of pH 4 and 7. Titratable acidity was calculated by titrating 5 mL of homogenized smoothie sample with 0.1 N NaOH to an end point of pH 8.1 (716 DMS Titrino, Metrohm, Herisau, Switzerland [5]).

2.3.3. Carotenoids

Carotenoids were spectrophotometrically monitored according to Nagata and Yamashita (1992) [6] with slight modifications. 5 mL of smoothie were mixed with 20 mL acetone-hexane (4:6). After passing a few minutes, two phases separated and upper layer was taken for lycopene and β-carotene measurements at 663, 645, 505 and 453 nm in a UV-visible spectrophotometer (Hewlet Packard, Model: 8453, Columbia, EEUU). Lycopene and β-carotene in acetone-hexane extracts were calculated according to the following equations:

$$\text{Lycopene (mg/ 100 mL)} = -0.0458\, A_{663} + 0.204\, A_{645} + 0.372\, A_{505} - 0.0806\, A_{453}$$

$$\beta\text{ - carotene (mg/ 100 mL)} = 0.216\, A_{663} - 1.22\, A_{654} - 0.304\, A_{505} + 0.452\, A_{453}$$

The analysis was carried out before and after each pasteurization treatment. All analyses were made by triplicate and results were expressed as mg L^{-1} of smoothie.

2.3.4. Statistical Analysis

Mean values (n = 3) were subjected to the least significant difference test (LSD) at $p < 0.05$.

3. Results and Discussion

3.1. Measurement of soluble solids content (SSC), pH and total titratable acidity (TA)

SSC in unheated smoothie was 5.10 °Brix and this value slightly increased after both thermal treatments. No significant differences by the type of thermal treatment were found. Initial pH value (4.50) was not significantly affected by treatments. There were no differences among the TA stability of the different treated samples, with 0.46% and 0.44% citric acid in unheated and MWP samples, respectively.

3.1. Color

The effects of MW and CP on L* and h° of smoothie are illustrated in Fig. 1 and 2. L* values increased after all treatments. MW treated samples for all doses showed higher L* values than in CP and in untreated smoothies ($p<0.05$). These results showed the MWP smoothies suffered a little change in luminosity. Commonly, MW treatments have been reported as a technique for better preserving the color in juices and smoothies compared to CP [7].

3.1 Carotenoids

Lycopene is an important intermediate in the biosynthesis of many carotenoids, including β-carotene, responsible for yellow, orange or red pigmentation, photosynthesis, and photo-protection [8]. According to results displayed in Fig. 3, the lycopene value significantly increased by different thermal treatment methods. The initial lycopene content in fresh smoothie was 10.56 ± 0.06 mg L^{-1}, whereas this amount increased significantly ($p<0.05$) after all heat treatment and reached to the maximum amount (12.93 ± 0.09 mg L^{-1}) in MW treatment. The results are supported by other study [9], which demonstrates thermal processing enhanced the nutritional value of tomatoes by increasing the lycopene content. Heating processing leads to extraction of lycopene from the matrix by breaking down cell walls, therefore making lycopene more accessible.

The β-carotene content was enhanced after heat treatment by both methods, but there were no significant differences among the type of treatment. The initial amount of β-carotene in unheated smoothie was 5.89 ± 0.07 mg L^{-1}, which increased by heat treatment and achieved the maximum value in combination of highest power and short duration in continuous MW (6.88 ± 0.09 mg L^{-1}). The results were confirmed by other authors [8, 9, 10] who reported heating treatment enhanced lycopene and β carotene in cooked tomato, carrot, spinach and pumpkin compare to the fresh product. In general, heating of vegetables resulted in break down of the cellulose structure of the plant cell and thus improves the bioavailability of carotenoids [11].

4. Conclusion

The use of MWP provide a fast heating of smoothie, useful for improving the initial carotenoids content. Its application in a continuous way with the equipment used in the current work was efficacy enough when compared to the CP method.

5. Acknowledgements

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Figures

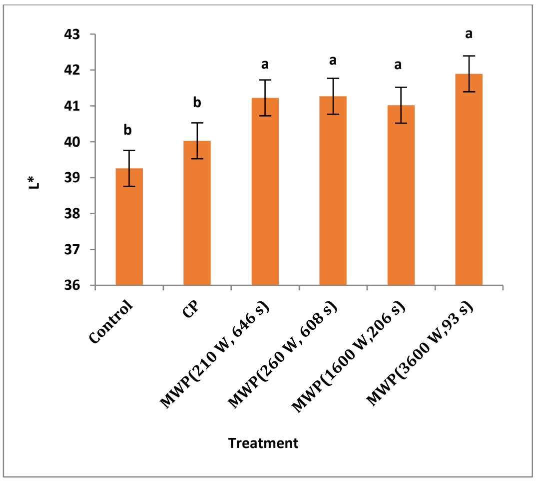

Figure 1. *Effect of different microwave doses (MWP) and conventional pasteurization (CP) treatments on L* of smoothie (mean ± SE, n=3).*

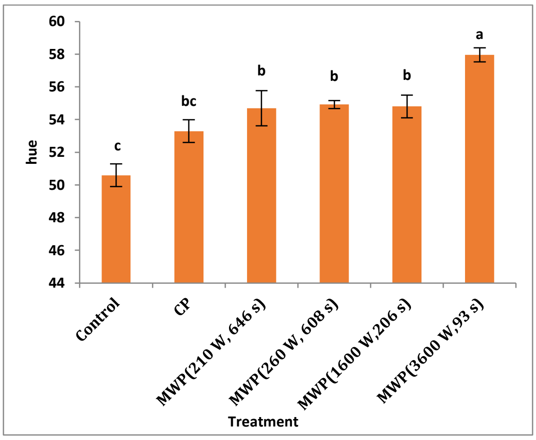

Figure 2. *Effect of different microwave doses (MWP) and conventional pasteorization (CP) treatments on hue angle smoothie (mean ± SE, n=3).*

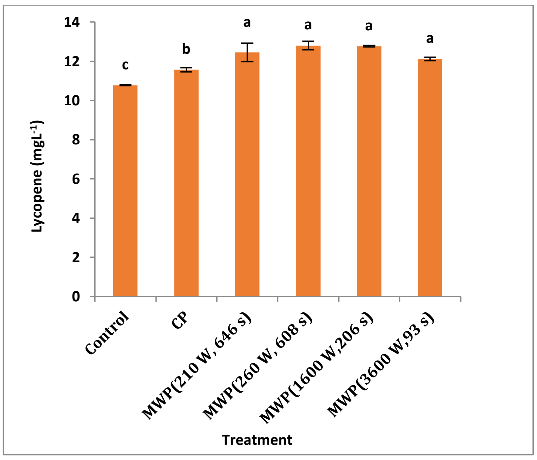

Figure 3. *Effect of different microwave doses (MWP) and conventional pasteorization (CP) treatments on the value of lycopene (mg L^{-1}) smoothie (mean ± SE, n=3).*