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Effects of electrical pre-treatment and alternative heat treatment applications on orange juice production and storage

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ABSTRACT

Electroplasmolysis (EP) as a pre-treatment and microwave (MW) and ohmic heating (OH) as an alternative to traditional heating were used in orange juice production, and the effects of these electrical methods on juice quality were investigated. Trials were done in six application groups with single electrical treatment and combinations. Orange juices were stored for six months at +4 °C and the analyses were performed in a two-month period. As a result of the electroplasmolysis application, more than an 8% increase in yield was determined. In addition, more than 95% PME inactivation was found in moderate (69–75 °C) temperature conditions for MW and OH applications. The results showed that the highest quality values, such as total pectin and ascorbic acid were determined on combined applications of electrical methods. The results suggested that juice yield and functional properties were increased by electroplasmolysis applications; electroplasmolysis and electrical heating applications gave better quality results comparing the conventional thermal heating (CH) in orange juice production. Quality characteristics of the juices can be preserved better and longer in the juices that are processed with electrical methods than the conventional methods.

Keywords: Orange juice; Electroplasmolysis; Microwave heating; Ohmic heating; Quality; Yield

1. Introduction

Orange juice is highly consumed in many countries and non-pasteurized fresh orange juice has a limited shelf life. Traditionally, thermal pasteurization is used to inactivate microorganisms to prolong shelf life on the one hand, and to inactivate heat-stable pectin methylesterase (PME) to prevent cloud loss on the other hand (Chen and Wu, 1998). PME is usually known to be more heat resistant than the common spoilage microorganisms of orange juice and inactivation of PME is generally used to determine the intensity of thermal processing during commercial pasteurization (Snir et al., 1996; Katsaros et al., 2010). Typically, for shelf stable orange juices, processing times for thermal pasteurization are equivalent to 90–95 °C for 60–90 s (Eagerman and Rouse, 1976; Demirdöven, 2009). This conventional treatment causes adverse effects on the final products, such as color alterations, flavor damages, vitamin and nutritional losses. Over the years, researchers have optimized time/temperature profiles to minimize the exposure of food to heat. Further, the newer process technologies may have the potential to reduce or even eliminate heat exposure. Some of these processes are not new, but have recently made significant advances towards commercialization (Vikram et al., 2005). As consumers are highly demanding minimally processed and fresh-like food products, the use of novel technologies is gaining popularity. The food industry is interested in novel electrotechnologies which inactivate enzymes and microorganisms without significant adverse

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effects on flavor and nutrients. There are a number of potential opportunities for exploiting the benefits of electrotechnologies like EP, OH and MW heating in food processing. These technologies can be applied in a variety of ways depending on the process requirements and the consumer demand.

EP, which is an electrical method, is effective in destroying cellular membranes (Bazhal et al., 2003). The method is based on the growth of pores in cell membranes as a result of electric field applications (Weaver and Chizmadzhev, 1996; Bazhal et al., 2003). EP application was found effective on improving yield and quality of citrus fruits (Flaumenbaum et al., 1986), tomato pulp (Yıldız, 2004), in sugar production (Gulyi et al., 1994), and in wine making (Kalmykova, 1993; Bazhal et al., 2001). In the literature is indicated the level of orange juice extraction efficiency of 36–46% (Carter and Barros, 1984). However, the rate of 30% remains at industrial applications. Therefore, the applications have to address to increase the efficiency of extraction. Electroplasmolysis application has been preferred as a non-thermal application. And it can be adapted to industrial production lines.

MW heating is another electrical thermal method that provides inactivation of enzymes and microorganisms quickly rather than the traditional heating methods. MW heating can be used in the food industry for blanching, cooking, pasteurization, preheating and drying. Recent studies show that MW heating also provides the transfer of functional components to food products (Canumir et al., 2002; Gerard and Roberts, 2004; Demirdöven and Baysal, 2009a).

OH is an electrical thermal method that is also known as electrical resistance heating, joule heating and electroheating. In recent years, the world's food industry has focused increasing attention on ohmic heating of food products. Several applications for ohmic heating in the food manufacturing industry include: heating liquid foods such as soups, stews and fruits in syrup; heat sensitive liquid processing; juices treated to inactivate enzymes (such as pineapple or papaya); blanching; thawing; starch gelatinization; sterilization; peeling of fruits; dehydration and extraction (Ramaswamy et al., 2005; Demirdöven and Baysal, 2009b).

In this study, oranges were used as raw material and samples were processed by using electroplasmolysis as pretreatment to determine effects on juice yield and microwave or ohmic heating were used as an alternative to traditional pasteurization at moderate tempraretures. The main purpose of this research was to determine combined effects of electroplasmolysis and microwave or ohmic heating applications on orange juice yield and some quality parameters at moderate (69–75 °C) temperature conditions. Furthermore, during six months of storage at +4 °C, the change in quality characteristics was compared with EP, MW, OH and CH processed lots.

2. Materials and methods

2.1. Material

Oranges (*Citrus sinensis*) of Valencia variety were used as raw material in this study. The oranges were purchased from Zumdieck Frozen and Canned Food Company (Salihli-Manisa, Turkey). They were stored at +7 °C and 80–90% humidity for a maximum of 48 h before processing.

2.2. Processing methods

EP was applied by a drum-type electroplasmolyzator that was designed by a research group in Ege University's, Food Engineering Department with the cooperation of Çermak Machine (Manisa, Turkey) for a previous research study (Baysal et al., 2007). The electroplasmolyzator has two cylinders with stainless steel pins, a voltage control unit that provides alternative electric current to the system and a feed unit that provides the contact between pins and samples. The detailed information about drum-type electroplasmolyzator was provided by Rayman et al. (2011). Oranges of specific diameter (7.0 ± 0.5 cm) were used and the distance between the cylinders of the drum-type electroplasmolyzator was adjusted so that the pins could be inserted 1 cm into the oranges. So, the distance between the pins was 4.5 cm, while the distance between the cylinders was 6.5 cm. Oranges processed with EP application were applied a voltage range of 40–200 V for 10 s time interval for pretreatment purposes. The experiments were replicated three times. Optimum voltage gradient was selected for maximum yield by using Response Surface Methodology (RSM). By the analysis of variance (ANOVA), voltage was found to be significantly important on the yield of juice at 95% confidence interval. The model was tested for lack of fit. The detailed information about optimization was provided by Demirdöven and Baysal (2012a). And productions were carried out at chosen optimum conditions for electroplasmolysis at 27.1 V/cm for 10 s operation time.

MW heating was used for the pasteurization of the orange juices. A modified MW oven (Model Arçelik MW 595, Istanbul, Turkey) with 2450 MHz operated at 540–900 W was used. The heating region of the MW oven contained a 3-m-long silicon hose (diameter of hose 8 mm-inside; 11 mm-outside) and a peristaltic pump for controlling flow (Watson Marlow [505U] Ltd., Falmouth, Cornwall, U.K.). Entrance and exit temperatures were measured by thermocouples. Flow rates between 40 and 80 ml/min at 540, 720, and 900 W were studied. The experiments were replicated three times. Flow rates and power were optimized for the pasteurization process by RSM and the PME activity was taken as a response. By the ANOVA, flow rate and power were found to be significantly important on PME activity at 95% confidence interval. Model was tested for lack of fit. The ANOVA results were determined as: R^2 (0.979); adj-R^2 (0.9645); Pred-R^2 (0.9167) and the coefficient of variation (CV) (6.27) for the model. By applying desirability function method, one solution was obtained for the optimum covering the criteria. Then the microwave applications were carried out at chosen optimum conditions at 50 ml/min flow rate and 900 W. The detailed information about optimization was provided by Demirdöven (2009).

OH experiments were conducted in a laboratory scale ohmic heating system; consisting of a power supply, an isolating transformer, a variable transformer and a microprocessor board. The detailed technical information about the system used was provided by Icier and Ilicali (2005). A teflon coated electronic temperature sensor (Omega Eng. Inc., Stanford, CT) with a compression fitting was used to measure temperature at the different sections of the sample in the test cell ($4 \times 4\,cm^2$). The distance between two electrodes was 0.04 m and the diameter of the electrodes was 0.025 m. The temperature of each sample was assumed uniform in the cell, since the maximum difference among the measured temperatures at different locations was approximately 1 °C. The experiments were replicated three times. The average temperature of the replicated heating experiments was taken as