ARTICLE IN PRESS

INNFOO-01399; No of Pages 8

Innovative Food Science and Emerging Technologies xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

journal homepage: www.elsevier.com/locate/ifset

Pasteurization of citrus juices with ohmic heating to preserve the carotenoid profile

Nawel Achir [a], Claudie Dhuique-Mayer [b,*], Thiziri Hadjal [b,c], Khodir Madani [c], Jean-Pierre Pain [d], Manuel Dornier [a]

[a] Montpellier SupAgro, UMR95 QualiSud, 1101 av. Agropolis, B.P. 5098, F-34093 Montpellier cedex 5, France
[b] CIRAD, UMR95 QualiSud, 73 av. J.F Breton, TA B-95/16, F-34398 Montpellier cedex 5, France
[c] Laboratoire de Biomathématique, Biophysique, Biochimie, et Scientométrie, Faculté des Sciences de la Nature et de la Vie, Université de Bejaia, 06000, Bejaia, Algeria
[d] Université de Montpellier, UMR95 QualiSud, CC 023, Place Eugène Bataillon, F-34090, Montpellier, France

ARTICLE INFO

Article history:
Received 21 May 2015
Received in revised form 22 October 2015
Accepted 5 November 2015
Available online xxxx

Keywords:
Citrus juices
ohmic heating
pasteurization
kinetics
modelling
carotenoids

ABSTRACT

This study was carried out to assess, for the first time, the effect of ohmic heating on the carotenoid profile of two citrus fruit juices: grapefruit and blood orange. Two heat treatments were designed to obtain pasteurization values of 50 and 150 min (Tref = 70 °C and z-value = 10 °C) with ohmic heating as compared to conventional heating. The results showed that xanthophyll losses could reach 70% for epoxyxanthophylls (*cis*-violaxanthin and *cis*-antheraxanthin) and 40% for hydroxyxanthophylls (β-cryptoxanthin, lutein, and zeaxanthin) with conventional heating, but losses were under 30% and 20%, respectively, with ohmic heating. Carotene species (lycopene and β-carotene) were stable regardless of the treatment. No negative non-thermal effects of ohmic heating were shown on carotenoids. Loss simulations of the studied carotenoids showed that the high temperatures reached with ohmic heating during pasteurization could substantially increase the organoleptic and nutritional quality of acid carotenoid-rich juices.

Industrial relevance: Citrus are the top fruit crops in terms of world trade. This craze for them -particularly orange and grapefruit- is notably due to their high content in organoleptic and nutritional compounds of interest and among them carotenoids. About 50% of the Citrus production is processed in juice. From the growing variety of products, minimal processed juices now have a significant market share. This work assessed for the first time the effect of ohmic heating, a thermal method for stabilizing juices while minimizing the impact on the juice quality, on the carotenoid profiles of blood orange and grapefruit juice. Pasteurization with ohmic heating was proven to be a very good alternative for protecting carotenoids and especially xanthophylls compared to conventional heating. These results will help in designing ohmic heating process parameters for optimizing the overall quality of carotenoid-rich fruit juices.

1. Introduction

Citrus fruits are grown in over 100 countries under tropical, subtropical and Mediterranean climates. They represent the top fruit crop in terms of world trade value (Khan & Kender, 2007). Citrus fruits have a high phytochemical content, including ascorbic acid, carotenoids and polyphenols (Dhuique-Mayer, Caris-Veyrat, Ollitrault, Curk, & Amiot, 2005; Ladanyia, 2008). Carotenoids are classified into two categories according to their structure: carotenes, non-polar hydrocarbons, and xanthophylls, which contain for the main either hydroxyl, epoxide, or keto functions in the end group (Britton, Liaanen-Jensen, & Pfander, 2004) (Fig. 1). These compounds are classified among food-bound exogenic antioxidants that are essential for counteracting oxidative stress. (Laguerre, Lecomte, & Villeneuve, 2007). Among citrus juices, sweet orange juice (*Citrus sinensis*) present the most complex carotenoid profile with a large type of xanthophyll. The main forms are esterified *cis*-violaxanthin, β-cryptoxanthin, lutein, zeaxanthin and *cis*-antheraxanthin (Dhuique-Mayer et al., 2005). Conversely, grapefruit juice (*Citrus paradisi*) has a simple carotenoid profile with two carotenes, i.e. lycopene and β-carotene (Fanciullino, Dhuique-Mayer, Luro, Casanova, Morillon and Ollitrault, 2006; Xu, Tao, Liu, & Deng, 2006).

Among the 10.9 million t of citrus products traded in 2009, sweet orange accounted for approximately 60% of citrus production in terms of both fresh fruit and processed juice consumption (FAOstat, 2015). Approximately 40% of all citrus produced worldwide is processed, with sweet orange and grapefruit juices representing major volumes (Johnson, 2000). Juice processing involves a stabilization step that boosts the shelf-life from 1 to 3 weeks for fresh fruits, and up to 18 months for pasteurized juices. Pasteurization is a heat treatment process that inactivates natural endogenous enzymes (pectin

* Corresponding author at: CIRAD, Département Systèmes de Production et Transformation, UMR Qualisud, TA B-95/16, 73, Av.J.François Breton, 34398 Montpellier cedex 5. Tel.: +33 04 67 61 44 82; fax: +33 04 67 61 44 33.
E-mail address: claudie.dhuique-mayer@cirad.fr (C. Dhuique-Mayer).

http://dx.doi.org/10.1016/j.ifset.2015.11.002

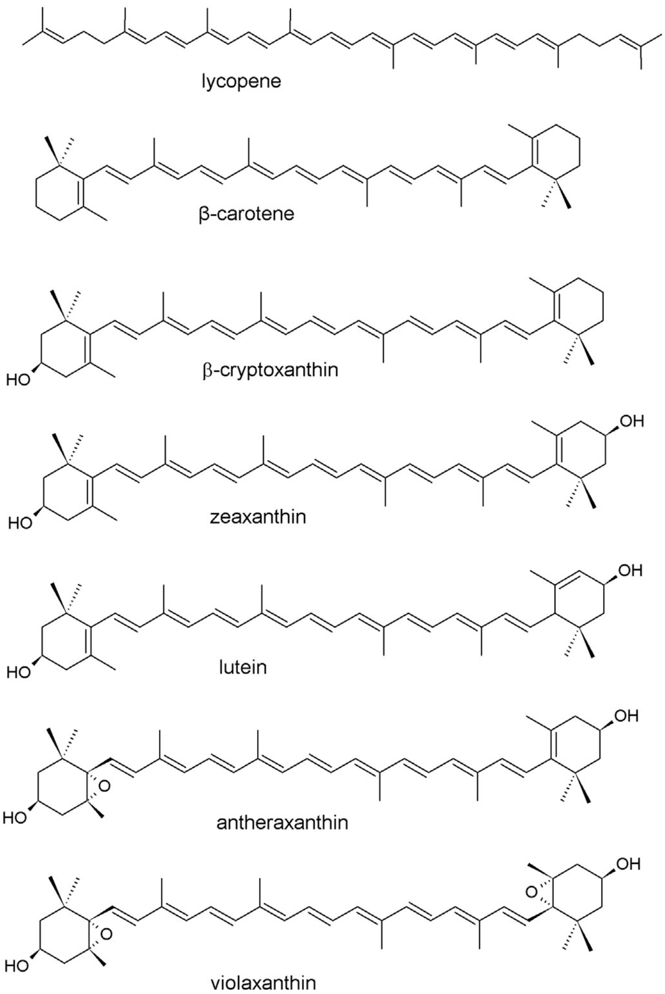

Fig. 1. Chemical structures of the major xanthophylls of blood orange juice and carotenes from grapefruit juice.

methylesterase, peroxidase, etc.) and microorganisms via heating at temperatures below 100 °C (Demirdoven & Baysal, 2015). This treatment, associated with the acidity of citrus juice (pH < 4), inhibits the development of heat-resistant pathogenic flora and enables storage at room temperature in aseptic hermetically sealed packaging.

Juice heat treatments are associated with quality depletion because of vitamin destruction and flavor component damage. Carotenoids, for instance, are sensitive to light, temperature and chemical exposure (metals, oxygen) during processing (Amaya, 2001). As heat can alter the nutritional and organoleptic properties, improvements in process technologies are sought to minimize juice heat exposure. This issue meets consumer demand for improved flavor and less-processed products (closer to fresh juice). Minimal processed juices now have a significant market share (Johnson, 2000).

Pasteurization is conventionally achieved by heat exchange, whereby heat is transferred by conduction from steam or hot water to the product. The heat exchange is more or less efficient depending on the pasteurizer design and technological choices. Ohmic heating ensures better thermal efficiency, so this technique is currently gaining ground and several continuous plants are now using it in the food industry (Butz & Tauscher, 2002; Demirdoven & Baysal, 2015). Ohmic heating devices are equipped with electrodes that enable the passage of alternating electrical current through the food product, thus generating internal heat as the result of electrical resistance, which is known as the Joule effect. Instant high volume heating occurs and gives a uniform temperature distribution, especially for liquid foods with high electrical conductivity (Demirdoven & Baysal, 2015; Goullieux & Pain, 2014; Icier, Yildiz, & Baysal, 2008; Jakób, Bryjak, Wójtowicz, Illeová, Annus and Polakovic, 2010).

This technology reduces thermal damage to food for many reasons. Indeed, heating and cooling are immediate (Sakr & Liu, 2014). This avoids over-processing of the food product, while achieving higher temperatures. Indeed, high temperature/short-term treatments are known to be efficient in destroying enzymes and bacteria while preserving the nutritional and organoleptic qualities. This could be explained by the fact that the temperature dependency is higher for microorganism destruction than for nutrient degradation, as illustrated in Table 1, where the z-values are generally under 10 °C for microorganisms and enzymes while being above 20 °C for compounds of organoleptic or nutritional interest. Fruit products processed using ohmic technologies have thus been found to have a better organoleptic properties (Leizerson & Shimoni, 2005a, 2005b; Pataro, Donsi, & Ferrari, 2011).

Non-thermal effects due to electrical fields represent a further feature of ohmic treatment efficiency (Butz & Tauscher, 2002). Indeed, as shown in Table 1, activation energies are higher for pectin methyl esterase inactivation but also for ascorbic acid degradation during ohmic heating in comparison to conventional heating. In addition, (Somavat, Mohamed, & Sastry, 2013) showed that degradation was faster for *Bacillus coagulans* in case of ohmic treatment (lower D-values). Electrical fields did not affect vitamin C degradation in acerola juices or orange juices (Mercali, Schwartz, Marczak, Tessaro, & Sastry, 2014; Vikram, Ramesh, & Prapulla, 2005). However, at high voltage, (Sarkis, Jaeschke, Tessaro, & Marczak, 2013) showed that the level of anthocyanins degradation was greater during ohmic-heating of blueberry pulp in comparison to conventional heating. To the best of our knowledge, no studies have been conducted on the effect of such technology on carotenoids. Vikram et al. (2005) only studied variations in orange juice colour using a chromameter, but no HPLC carotenoid quantification was done (Vikram et al., 2005).

Our study was thus carried out with the aim of studying carotenoid degradation in blood orange and grapefruit juices during conventional heating, i.e. by convection-diffusion, and ohmic heating. The carotenoids monitored were both xanthophylls and carotenes, which encompass the main structural diversity of this molecular family. In addition, previously published degradation parameters obtained on the same citrus juices matrices were used to represent their behavior during thermal processing. The findings of this study could therefore contribute to the lack of information about nutrient behavior during ohmic heating.

2. Material and methods

2.1. Juices

Sanguinelli variety blood oranges (*Citrus sinensis* L. Osbeck) were from the Benyoub agricultural field (Bejaia, Algeria) and South American pink grapefruits (*Citrus paradisi* Macf) were purshased in a market. The fruits were cut in half and pressed using a domestic juicer (Moulinex Masterchef 470, France). The juice was filtered through a stainless steel sieve (1 mm). The freshly pressed juice was placed in amber glass bottles, and stored under nitrogen at −20 °C prior to analysis or heat treatment.

2.2. Heating devices

For conventional heating, 4 mL of juice were placed in 10 mL sealed glass tubes. Three tubes per test were immersed in an oil bath under temperature control (Memmert, Legallais, France). With this small juice volume, the temperature was homogeneous throughout the tube. A digital temperature probe (EKT 3001, Heidolph, Germany) fitted to a reference tube was used to measure the juice temperature during the thermal experiments. After thermal treatment, the three tubes were rapidly cooled in an ice bath.