LWT - Food Science and Technology 55 (2014) 34–42

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Effects of infrared radiation heating on peeling performance and quality attributes of clingstone peaches

Xuan Li [a], Ang Zhang [a, b], Griffiths G. Atungulu [a], Michael Delwiche [a], Rebecca Milczarek [c], Delilah Wood [c], Tina Williams [c], Tara McHugh [c], Zhongli Pan [a, c, *]

[a] Department of Biological and Agricultural Engineering, University of California at Davis, Davis, CA 95616, USA
[b] College of Enology, Northwest Agriculture and Forestry University, Yangling, Shanxi 712100, China
[c] Western Regional Research Center, USDA Agricultural Research Service, Albany, CA 94710, USA

ARTICLE INFO

Article history:
Received 2 May 2013
Received in revised form
26 August 2013
Accepted 28 August 2013

Keywords:
Infrared radiation
Clingstone peach
Scanning electron microscopy
Temperature profiles
Peeling evaluation

ABSTRACT

Salinity and wastewater disposal problems associated with the conventional wet-lye method for peeling clingstone peaches result in considerable negative environment impacts. The efficacy of using infrared (IR) heating as an alternative method for peach peel removal was investigated to eliminate the use of water and chemicals. Peaches sorted into three size categories were double-sided heated under IR with three emitter gaps for a range of heating times from 90 s to 180 s. Wet-lye peeling was used as a control. Results showed that 180 s IR heating for medium sized peaches under an emitter gap of 90 mm yielded 84 mm^2/100 mm^2 peelability and 90 g/100 g peeling yield, produced peeled products with comparable firmness and color to wet-lye peeled peaches. Surface temperature increased rapidly (> 00 °C) during IR heating whereas the flesh temperature at 16 mm beneath skin remained relatively low (<45 °C). Thermal expansion of cell walls and collapse of cellular layers adjacent to skins were found in IR heated peaches and differed from the micro-structural changes observed in lye heated samples, indicating their mechanistic difference. Promoting uniform and rapid surface heating is essential to further develop IR heating as a non-chemical method for peach peeling.

1. Introduction

The current industrialized wet-lye method for peeling clingstone peaches has been identified as a very energy and water intensive process (Masanet, Worrel, Graus, & Galitsky, 2007; Pandrangi & Barringer, 2000). After lye peeling, the wastewater contains very high salinity (100–200 g/L) and organic loads, resulting in a high cost of wastewater management and negative environmental footprints (Garcia & Barrett, 2006a, 2006b; Masanet et al., 2007; Milczarek & McCarthy, 2011; Schlimme, Corey, & Frey, 1984; Shi, Le Maguer, Wang, & Liptay, 1997; Wongsa-Ngasri, 2004). There is a great need to develop a sustainable and non-chemical method for peeling clingstone peaches with improved energy and water efficiency and reduced generation of peeling effluents. Our recent research on tomato peeling has found that utilizing the infrared (IR) radiation heat for peeling tomatoes has a great potential to eliminate the reliance on chemicals and water for peeling while providing high quality peeled products (Pan, Li, Bingol, McHugh, & Atungulu, 2009; Li, 2012). The developed IR peeling method could be extended to peel other fruits, such as clingstone peaches. The IR radiation has a rapid surface heating characteristic that allows effective heating of only a shallow layer of the fruit or vegetable surface to achieve peel separation while preserving the nutrients and quality in the edible portion of the products. Because IR radiation does not require any heating medium, such as lye, water, or steam, the IR heating technique could be developed as a novel dry-peeling method for peach peeling.

Clingstone peaches (*Prunus persica*) are traditionally peeled with wet-lye (Hart, Graham, Huxsoll, & Williams, 1970). In the wet-lye process, complex lye diffusion and chemical reaction processes conducted at a high temperature synergistically lead the skin to fully loosening. The loosened peels and tissues weakened as a result of the thermal and chemical actions are easily removed by passing peaches under high-pressure sprays of water. A typical procedure of using wet-lye method for peeling clingstone peaches involves three steps: cascade hot lye over peach halves for 3 s–10 s, temper the peach halves in a high temperature atmosphere for 15 s–20 s to allow the peach skin fully react with the lye, and wash off the

* Corresponding author. Western Regional Research Center, USDA Agricultural Research Service, Albany, CA 94710, USA. Tel.: +1 510 559 5861; fax: +1 510 559 5851.
E-mail addresses: zlpan@ucdavis.edu, zhongli.pan@ars.usda.gov (Z. Pan).

0023-6438/$ – see front matter Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.lwt.2013.08.020

loosen peels with high pressure sprays of water. Superior to other peeling methods, such as abrasive peeling and steam peeling, wet-lye method demonstrates a better suitability at a large scale operation for peeling peaches of different shape, size, and varieties (Setty, Vijayalakshimi, & Devi, 1993). However, peaches after treatment with hot lye requires thorough water wash to remove both the lye disintegrated peels and residual lye on the peach surface (Hart et al., 1970; Setty et al., 1993), which can cause discoloration and is more susceptible to affect negatively the quality of final processed products (Walter & Schadel, 1982).

Application of IR radiation to improve the food quality and safety has been evidenced in various processes, such as quality inspection, drying, blanching, and sterilization (Pan et al., 2009). Utilization of the surface heating characteristics of IR radiation in the peeling process has not yet been fully investigated. The earliest report in literature of using IR heat to assist lye peeling was known as combined dry-caustic peeling, which utilizes the IR heat to promote the chemical reactions occurring on vegetable surfaces sprayed with lye (Sproul, Vennes, Knudson, & Cyr, 1975). Peeling trials using the combined lye and IR method for peeling white potatoes resulted in a significant decrease in peeling loss and reduced usage of lye and water. At present, the ever-increasing environmental concerns and dwindling water supply escalate the costs of using water and chemicals in peeling operations. Restrictive regulations imposed by state governments underlie the pressing need for economical and sustainable peeling technologies that can eliminate the use of water and chemicals in peeling while maintaining high quality peeled products. Complete elimination of lye and water in peeling was fulfilled in our recent studies of using IR heat for sustainable tomato peeling (Li, 2012; Pan et al., 2009). The thermal shock induced by IR caused loosening of the skin and thereby promoted peel separation. Our results obtained from tests conducted during multiple harvest seasons showed that IR dry-peeling of tomatoes achieved a similar peelability but yielded lower peeling loss and firmer peeled product for the same or slightly longer peeling time when compared to regular lye peeling method (Li, 2012; Pan et al., 2009; Li, Pan, Bingol, McHugh, & Atungulu, 2009).

Characterization of the IR dry-peeling process for peach peeling requires investigating several key processing parameters, especially the IR radiation intensity and heating time (Krishnamurthy, Jun, Irudayaraj, & Demirci, 2008; Pan et al., 2009). IR radiation intensity affects the heat fluxes impinged on the fruit surface. The higher IR the heat flux that irradiates onto the fruit surface, the more effective the IR radiation will be for peeling. When peach is subjected to a double side IR heating scenario, the degree of exposure of fruit surface to the IR radiation source is largely influenced by the emitter gap that is the distance between two parallel IR emitters. In the double sided heating scenario, manipulating the emitter gap can be an effective way to adjust IR radiation intensity and thus ensure a sufficient radiation heat exchange between the IR emitters and the peach surface, which fundamentally reflected as the changes of the radiation view factor (Howell, Siegel, & Menguc, 2010). Besides radiation intensity, the IR heating time is another important factor which directly affects the heating and peeling performance. A longer exposure to IR heating may provide sufficient thermal energy but leads to deterioration of peach quality and nutritional loss due to overheating, whereas less heating time may not be able to achieve desired peel separation and thus reduces the peelability. Moreover, the heating performance is also affected by the peach size. Peaches of various sizes absorb different amounts of thermal energy under the same heating time and heating configuration and consequently have different peeling performances and peeled product qualities. In order to ensure good peelability and high quality of peeled end products, an important aspect of the IR dry-peeling method is to heat the fruit surface rapidly to a proper temperature level while maintaining the fruit interior temperature as low as possible. Therefore, identification of appropriate heating conditions for peach peeling and monitoring the temperature changes on the peach surface and in the interior flesh during IR heating become imperative to characterize. To provide insight into the effect of IR heating on quality changes, characterizing the micro-structural changes and morphological features of peach tissues as affected by IR is of particular interest to examine.

This research aimed at investigation of the efficacy of using the novel IR dry-peeling method for peach peel removal in order to eliminate the usage of lye. The specific objectives of this study were to (1) characterize the IR dry-peeling process by comparing the peeling performance and quality attributes of IR peeled peaches with regular wet-lye peeling and identify the effective IR heating conditions; (2) determine the temperature distributions on the peach surface and interior during and after IR heating; and (3) examine the micro-structural changes in peach cellular tissues nearby peels as affected by IR heating and compared with fresh and lye treated peaches.

2. Materials and methods

2.1. Peaches

Due to the variability of harvesting dates, clingstone peaches (*P. persica*) of four cultivars (cvs.), including Ceres Carson, Stanislaus, Loadel, and Ross, were used for this study. These clingstone peaches were grown in the central valley of California and were retrieved from a commercial peach processing plant throughout the 2010 harvesting season. All the peeling experiments were carried out immediately after the reception of each commercial load of peaches and completed within two or three days. Peaches were stored in an incubator at 2 ± 1 °C. Prior to peeling, peaches were allowed to equilibrate to the ambient temperature. This step, which took at least four hours, ensured all the peaches had the same initial surface temperature (23 ± 2 °C) before IR and lye peeling. Depending on the harvesting dates, different peach cultivars were used for different sets of tests. Only peaches without any visual defects were used in this study.

Physical properties, including peach mass, peach size, surface area, and flesh color, were assessed for fresh peaches randomly selected from each cultivar. The peach mass was measured by using an electronic digital balance with a sensitivity of 0.01 g. The peach size – defined as the peach cheek diameter – was measured by using a digital caliper with an accuracy of 0.1 mm. The surface areas of peaches were predicted by considering each peach as a spherical model. Validation of the accuracy of the spherical model was performed by comparing the predicted surface area from the spherical model with measured surface area obtained by using a traditional tape method (Clayton, Amos, Banks, & Morton, 1995). To minimize the influence of recessed areas around the peach stem and the indent area along the suture line, tapes were cut into narrow pieces and attached to the peach surface. The flesh color of fresh peaches was measured by using a Minolta Chroma Meter (model CR200, Minolta Corp., Ramsey, Japan) under the CIE L^*a^*b color space. Two pieces of peach skins with a thickness of 0.5 mm were removed from each side of the peach cheeks by a food slicer (model 620, Edgecraft Corp., Avondale, Pennsylvania, USA). Measurements of flesh color were conducted instantly on these two areas to avoid browning and oxidation. Average value of the two measurements was reported for each peach.

2.2. Peeling procedures

2.2.1. IR dry-peeling

A picture and a schematic diagram of the IR heating setup are shown in the Fig. 1. The laboratory scale IR heating unit consisted of