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Tomato peeling by ohmic heating with lye-salt combinations: Effects of operational parameters on peeling time and skin diffusivity

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ABSTRACT

Ohmic heating without lye has shown promise in tomato peeling; however the use of lye is known to yield high peeled-product quality. In this work, we studied the operational parameters of the ohmic peeling process, specifically, the influence of salt-lye concentration combinations and field strength on time for skin cracking during ohmic peeling. We further investigated the influence of electric fields on the lye diffusivity through tomato skin. The treatments of 0.01/0.5% NaCl/NaOH at 1610 V/m and 0.01/1.0% NaCl/NaOH at 1450 V/m were the conditions that required the shortest time for cracking. For NaCl/KOH mixtures, 0.01/0.5% NaCl/KOH at 2020 V/m and 0.01/1.0% NaCl/KOH at 1450 V/m required the shortest time for cracking. Studies on diffusion through the tomato skin showed that ohmic heating significantly improved lye diffusion ($p < 0.05$) at both 50 and 65 °C. After an initial period, diffusivities of lye peeling with ohmic heating were greater than those without ohmic heating at both 50 and 65 °C, confirming that the electric field enhances diffusion of NaOH through the tomato skin.

1. Introduction

Lye and steam are the most commonly used peeling methods in the processed tomato industry. Both have their own advantages and disadvantages. Lye peeling, which was previously banned in some states, has been resurrected, particularly in the Midwestern states of the United States, because it provides smooth surfaces of peeled tomatoes which cannot be achieved by steam peeling. However, with lye peeling, wastewater and used lye generate environmental problems and are difficult and costly to treat. Therefore, research is necessary to reduce lye concentration, and recycling of used lye.

Floros and Chinnan (1988) have shown that under steam peeling, cuticular waxes melt, and breakdown of pectins and carbohydrate hydrolysis occur. These phenomena, accompanied by internal pressure rise due to high temperatures result in cell rupture and skin separation. Models of the chemical peeling process have been attempted by Chavez et al. (1997) and Barreiro et al. (2007). Alternative methods of peeling have also been explored in the literature, including enzymatic peeling (Toker and Bayindirli, 2003), and infrared peeling (Li et al., 2014a, b).

From our own previous studies (Wongsa-Ngasri and Sastry, 2015), ohmic peeling showed promising results for tomato peeling, indicating that under some conditions, good peeled product quality was possible. In that work, electric field strength, concentration and initial temperature of NaCl were found to be important factors in optimizing the peeling process. Since the use of lye (sodium or potassium) hydroxide is known to be effective for tomato peeling, it is worth investigating the efficacy of a peeling process that uses lye-salt mixtures in combination with ohmic heating, and to investigate reasons for the efficacy of the technology. Accordingly, our objectives were to determine: 1) the effects of field strength and salt-lye composition on the time required for peeling, and 2) the effect of electric field and temperature on the diffusivity of sodium hydroxide through tomato peel.

2. Materials and methods

2.1. Experimental setup

The system to investigate the operational conditions of lye and ohmic tomato peeling is consisted of a 60 Hz AC power supply and controller connected with an ohmic heater unit, which was made from an open Pyrex glass T-tube cylinder of 0.201 m length and 0.051 m inside diameter. The setup diagram is presented by

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Nomenclature

C	concentration, mol/l
C_1	concentration in donor compartment of test cell, mol/l
D	diffusivity, m^2/s
l	thickness of the skin, m
t	time, s
x	length coordinate

Wongsa-Ngasri and Sastry (2015) and is not presented here. Two titanium electrodes were securely placed at the left and right ends of the T-tube glass via a pair of spacers and connected to an alternating current power supply (0–1000 V). The temperature of the liquid medium for each experiment was continuously measured using a Teflon coated type-T thermocouple (Omega Eng. Inc., Stamford, CT) and recorded by a data logger (21X, Campbell Scientific, Inc., Logan, Utah). A tomato was placed in the chamber, which was then filled with the medium. The thermocouple was also placed near the tomato at the same position and depth for every run. Voltage, current and time were recorded by the data logger.

2.2. Experimental procedure

Roma tomatoes of the same batch and color, were obtained from local department stores for use in experiments. All experiments were set at specific conditions, begun at room temperature (25 ± 1 °C) and stopped when the tomato peel cracked. Conditions and results were recorded in triplicate using a video camera (Canon ES900, Japan) synchronized with a digital stopwatch. At a preassigned time, the preset AC power was turned on, and the data logger began recording data at the same time. Subsequently, the skin cracking time on the videotape was synchronized with that of the data logger. After cracking occurred, or the temperature of the medium reached 100 °C (whichever came first), the experiment was stopped, and the tomato was peeled by washing in water.

2.2.1. Effects of electric field strength and type of fluid medium

We studied effects of electric field strength (V/m) and type of fluid medium (sodium chloride-sodium hydroxide, sodium chloride-potassium hydroxide mixtures). The experimental conditions are described in Table 1. The gap between electrodes was fixed at 6.2 cm, which was the minimum gap necessary to accommodate one tomato.

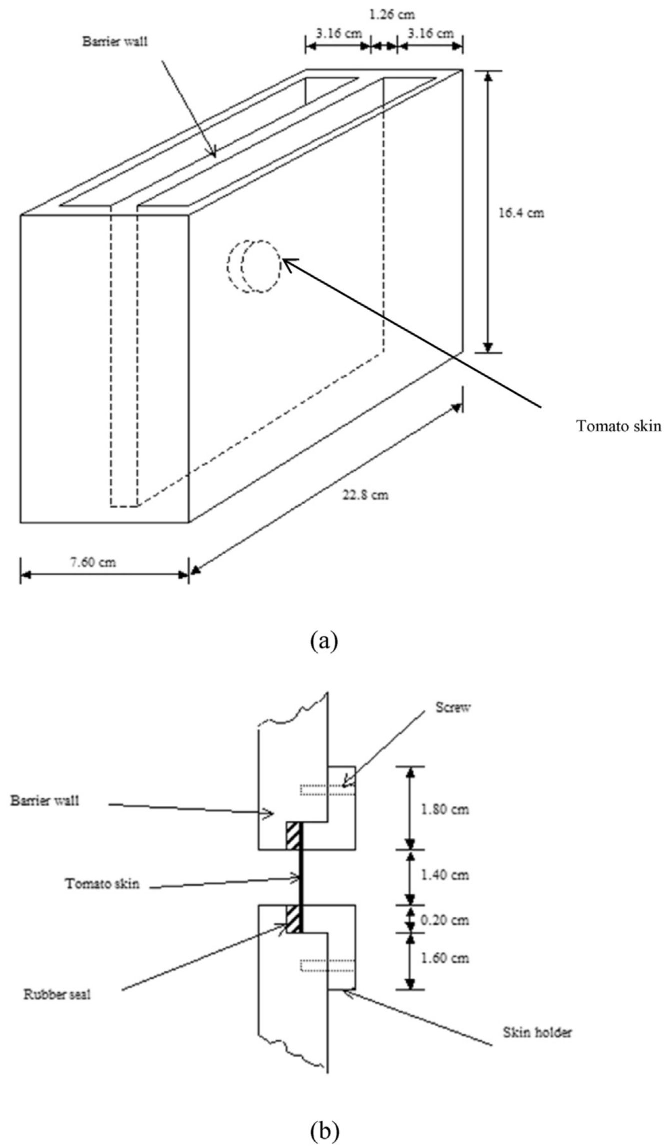

Fig. 1. (a) The diffusivity cell and (b) tomato skin holder detail.

2.2.2. Diffusion analysis during tomato lye and ohmic peeling

2.2.2.1. Preparation of tomato skin samples. Roma tomatoes (same batch and color, taken as indication of maturity) obtained from local department stores were used in experiments. Samples were cut in a cylindrical shape, and flesh was carefully removed from them by a sharp razor to obtain 0.02 ± 0.001 cm thick skins. The

Table 1
Experimental treatments for studying effects of electric field strength, and concentrations of NaCl/NaOH and NaCl/KOH mixtures on tomato peeling.

NaCl/NaOH mixture (% w/v)	Field strength (V/m)							
0.01/0.01	–	–	–	–	–	3230	4840	6450
0.01/0.05	–	–	–	–	–	3230	4840	5650
0.01/0.1				1610	2420	3230	–	–
0.01/0.5	–	–	1210	1610		–	–	–
0.01/1.0	645	806	1130	1450	–	–	–	–
0.03/0.01	–	–	–	–	–	3230	4840	–
NaCl/KOH mixture								
0.01/0.5	–	806	1210	1610	2020	–	–	–
0.01/1.0	–	806	1130	1290	–	–	–	–