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Tomato peeling by ohmic heating: Effects of lye-salt combinations and post-treatments on weight loss, peeling quality and firmness

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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. This investigation was aimed at determining whether a combination of ohmic heating and low lye concentrations could be synergistic. The results indicated that 0.01/0.5% NaCl/KOH at 2020 V/m was the best condition for tomato peeling in terms of quality, weight loss, and peel cracking time. Further, the treatment showed weight loss that was not significantly different from conventional lye peeling at 7% NaOH and 7% KOH ($p < 0.05$). NaCl/NaOH mixtures also showed good results, but the quality of products was lower than that using the same concentration, but a higher field strength with NaCl/KOH mixtures. However, no improvement was found using NaCl/$CaCl_2$ and NaCl/NaOH/$CaCl_2$ mixtures which were also found difficult to use due to turbidity and cleaning difficulties. A post-peeling treatment by ohmic heating was investigated to improve firmness of ohmically peeled tomatoes. It was found that the best conditions were 2% $CaCl_2$ solution at a field strength of 403 V/m for 1 and 5 min, and 484 V/m for 5 min.

Industrial Relevance: Our earlier work had shown that ohmic heating resulted in peeling of tomatoes that were immersed in salt solutions. The current work details the impact of using small concentrations of lye (either sodium or potassium hydroxide) on peeling loss and quality. Also, we investigate the potential use of calcium chloride, both as peeling solution or as a post-peeling infusion as it impacts firmness of tomatoes. We show that there are ranges of operating conditions which provide yield and quality comparable to conventional lye peeling at far lower lye concentrations, resulting in potentially significant environmental benefit to companies currently using lye peeling.

1. Introduction

Lye and steam are commonly used peeling methods in the processed tomato industry, with their individual strengths and shortcomings. Lye peeling provides smooth surfaces of peeled tomatoes which cannot be achieved by steam peeling. However, this comes at a cost of wastewater and used lye with the attendant environmental problems. Therefore, it is worthwhile investigating methods to reduce lye concentration while retaining peel quality and to explore the use of firming agents such as calcium chloride.

It has been reported that calcium could improve the firmness of canned tomatoes. Kertesz, Tolman, Loonti, and Ruyle (1940) showed that the combination of salt tablets which contained calcium chloride ($CaCl_2$) and sodium chloride (NaCl), could increase the drained weight of canned tomatoes. They also claimed that calcium could be used in commercial canning of whole tomatoes since it would interact with pectin to form a calcium pectate gel around the tomato tissue, thereby acting as a firming agent, and providing higher drained weight (Jacob, 1951). FDA allows the use of purified calcium chloride, calcium sulfate, calcium citrate, monocalcium phosphate, or any two or more of these as firming agent, comprising no more than 0.026% calcium by weight of the final canned tomato. However, the calcium content can be up to 0.1% for diced tomatoes (Gould, 1974). Calcium pectate, which forms in the middle lamella and cell wall, increases structural strength and firmness and resistance to polygalacturonase attack (Grant, Morris, Rees, Smith, & Thom, 1973). More recent work (Floros & Chinnan, 1988) has shown that under steam peeling, cuticular waxes melt, and various biochemical reactions including breakdown of pectins and carbohydrate hydrolysis occur. These changes accompanied by internal pressure rise due to high temperatures result in cell wall rupture and skin separation. Modeling of the chemical peeling process has also been attempted (Barreiro, Sandoval, Rivas, & Rinaldi, 2007; Chavez, Luna, & Garrote, 1997).

Alternative methods of peeling have also been explored in the literature, notably enzymatic peeling (Toker & Bayindirli, 2003), and infrared peeling (Li, Pan, Atungulu, Zheng, Wood, Delwiche and McHugh, 2014a; Li, Pan, Atungulu, Wood, & McHugh, 2014b). From our own previous studies (Wongsa-Ngasri & Sastry, 2015), ohmic treatment of tomatoes within salt solution showed promising results for peeling,

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indicating that under some conditions, good peeled product quality was possible. In our work, electric field strength, concentration and initial temperature of NaCl were found to be important factors in optimizing the peeling process. However, those studies were intended to study the feasibility of ohmic peeling, and did not seek to compare ohmic treatment with lye peeling. Further, it was not clear whether or not ohmic peeling yielded weight losses and product quality that were competitive with lye peeling.

Since lye peeling generates less weight loss and better peeled product quality than other methods, it is worth investigating whether it might be combined with ohmic peeling, to mutually enhance the advantages of both methods. If the concentration of lye could be significantly reduced when compared to lye peeling, substantial environmental benefits could result. Consequently, the objectives of this study were to investigate possibilities of using (1) various combinations of lye and ohmic heating on tomato peeling, in particular focusing on the influence of lye concentration, medium composition, and field strength on the peeling quality and weight loss of ohmic/lye combination treated tomatoes, and (2) a post-peeling treatment by ohmic heating to enhance firmness of ohmic-peeled tomatoes in $CaCl_2$ solution.

2. Materials and methods

2.1. Experimental setup

A system was set up to investigate the potential of using combinations of lye and ohmic treatment on tomato peeling. A schematic diagram is illustrated in Fig. 1. The system consisted of an AC power supply (0–1000 V) and controller connected to an ohmic heater unit, made from an open Pyrex glass T-tube cylinder of 0.201 m length and 0.051 m inside diameter, with two titanium electrodes at the left and right ends via a pair of spacers. The temperature of the liquid medium was continuously measured during each experiment 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.

2.2. Experimental procedure

All experiments were begun at room temperature (25 ± 1 °C). Conditions and results were recorded in triplicate using a video camera (Canon ES900, Japan) synchronized with a digital stopwatch. At a predetermined time, the preset AC power was turned on, and the data logger began recording temperature, voltage and current data simultaneously. Subsequently, the skin cracking time on the videotape was synchronized with that of the data logger (cracking could be clearly visualized and identified as the moment when the skin relaxed visibly and was unable to hold internal pressures thereafter). After skin cracking occurred, or the temperature of the medium reached 100 °C (whichever came first), the experiment was terminated, and the tomato peeled by washing in water. The peeling quality (determined using criteria described by Wongsa-Ngasri & Sastry, 2015) was recorded in every experiment. The basis for comparison was a conventional lye-peeled tomato of similar ripeness and dimensions, with a smooth peeled surface, which was rated a 5 on a 5-point scale. Thus, on the quality scale: 5, represented very good quality; 4, good quality; 3, average quality; 2, poor quality; and 1, very poor quality. A view of the peeled tomato was recorded on videotape as well.

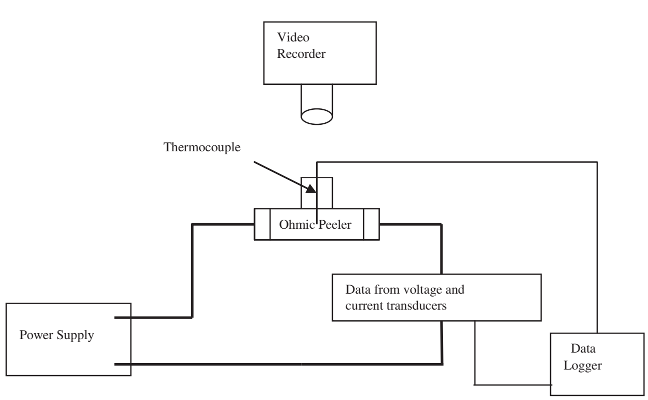

Fig. 1. Schematic diagram of the experimental setup.

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

We studied effects of electric field strength (V/m, measured by dividing applied voltage by electrode gap) and type of fluid medium (sodium chloride-sodium hydroxide (NaCl-NaOH), sodium chloride-potassium hydroxide (NaCl-KOH), sodium chloride-calcium chloride (NaCl-$CaCl_2$), and sodium chloride-sodium hydroxide-calcium chloride (NaCl-NaOH-$CaCl_2$) 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.

All tomatoes were individually weighed before and after peeling. Weight losses were measured (Eq. (1)) and compared with conventional lye peeling.

$$\%\text{Weight Loss} = \frac{(\text{Weight before peeling} - \text{Weight after peeling})}{\text{Weight before peeling}} \times 100\% \quad (1)$$

2.2.2. Effects of ohmic post-treatment on firmness

Various peeling and post processing treatments were investigated to determine their effects on firmness of ohmically-peeled tomatoes. First, tomatoes were ohmically peeled in 0.01/0.5% *w/v* NaCl/KOH mixture at 125 V (2020 V/m), for approximately 1 min. They were peeled and cut symmetrically into 2 pieces. Each piece was differently treated and its firmness was measured and compared between the following treatments.

Treatment I: Tomato without any treatment.

Treatment II: Tomato submerged in $CaCl_2$ solution for specific concentrations and time.

Table 1
Experimental treatments for studying effects of electric field strength, and concentrations of NaCl/NaOH, NaCl/KOH, NaCl/$CaCl_2$, NaCl/NaOH/$CaCl_2$ mixtures, and controls (7% NaOH and 7% KOH, conventional treatment) 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 (% w/v)								
0.01/0.5	-	806	1210	1610	2020	-	-	-
0.01/1.0	-	806	1130	1290	-	-	-	-
NaCl/$CaCl_2$ mixture (% w/v)								
0.01/1.0	-	-	1610	2020	2420	-	-	-
0.01/2.0	-	-	1210	1610	2020	-	-	-
NaCl/NaOH/$CaCl_2$ (% w/v)								
0.01/0.5/0.2	-	806	1210	1610	-	-	-	-
0.01/0.5/0.5	-	806	1210	-	-	-	-	-
Conventional Treatments								
NaOH (7%)	-	-	-	-	-	-	-	-
KOH (7%)	-	-	-	-	-	-	-	-