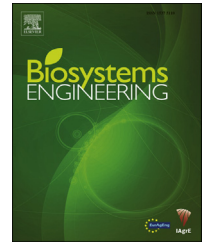


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Research Paper

A pilot scale electrical infrared dry-peeling system for tomatoes: Design and performance evaluation

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A pilot scale infrared dry-peeling system for tomatoes was designed and constructed. The system consisted of three major sections including the IR heating, vacuum, and pinch roller sections. The peeling performance of the system was examined under different operational conditions using tomatoes with different cultivars and sizes. Three lines of tomatoes were heated and processed at the same time at a residence time of 125 s and achieved a percentage of fully peeled tomatoes of 85%, a peeling yield of 82%, and an average thickness of peeled tomato skin of 0.75 mm. When tomatoes were loaded as a single line, the required heating time was reduced to a range from 80 to 100 s, depending of tomato size, for achieving the same level of peeling percentage and yield. The presence of the vacuum section could achieve cracks in 100% of the tomatoes after IR heating. The peeled products from IR heating had high firmness and appealing surface integrity, which indicated desirable quality characteristics. Because the dry-peeling is a chemical- and water-free process, residuals of tomato skins after IR peeling could be easily utilised as value-added by-products.

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1. Introduction

Sustainability in food processing has become a driving force in the development of novel food processing technologies. Small energy and carbon footprints, high water-use efficiency, wastewater management, and minimal chemical contamination have become critical factors in decision-making in

terms of choices of food production and processing systems (Roy et al., 2009). In the fruit and vegetable industry, many unit operations such as peeling, blanching, and pasteurisation are energy- and water-intensive and result in huge amounts of wastewater with high salinity and organic loads (Das & Barringer, 2005; Milczarek & McCarthy, 2011; Pan, Li, Bingol, McHugh, & Atungulu, 2009; Rock, Yang, Goodrich-Schneider,

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& Feng, 2011; Setty, Vijayalakshimi, & Devi, 1993). The conventional peeling process is carried out using hot lye solution or pressurised steam. These peeling methods have been developed and optimised since the 1940s and have gained widespread application among fruit and vegetable processors in the United States (Masanet, Worrel, Graus, & Galitsky, 2007; Matthews & Bryan, 1969; Rock et al., 2011). But, in recent years, minimising water and chemical usage as well as the costs associated with disposal of peeling effluents have become important goals for the tomato industry. The ever-tightening environmental protection regulations and dwindling water supply escalate the costs of conventional peeling operations. For example, the hot lye peeling process used in the California tomato processing industry produces about 25% of solids in the waste stream, which amounts to 703,068 t (i.e., 775,000 U.S. tons) of solids annually (Pan et al., 2009). The cost of managing the dissolved solids in the peeling effluent at processing plants by various industrialised technologies ranges from 258 to over \$8000 t⁻¹ (Pan et al., 2009). Assuming an average cost of \$300 t⁻¹, the total cost of treating the wastes from the peeling processes in California alone is \$233 million, which should be substantially reduced through the elimination of chemicals and water usage in peeling (Li, 2012). There is an urgent need for sustainable peeling alternatives that can effectively peel tomatoes while minimising peeling losses and improving product quality.

Our previous studies have shown that IR radiation heating can be used for tomato peeling and can eliminate the use of water, chemicals and steam in the peeling process (Li, 2012; Pan et al., 2009). A novel IR-dry peeling method has been developed from the concept of utilising the rapid surface heating characteristics of IR for loosening tomato skins and thereby promoting peeling (Li, 2012; Pan et al., 2009). Rapid IR heating heated and released only a shallow layer of tomato skin (less than 1 mm) while preserving the quality and nutritional values of peeled tomatoes. Based on the results from several consecutive seasons, compared to conventional lye peeling, IR dry-peeling of tomatoes had a lower peeling loss, a thinner thickness of peeled-off skin, and a firmer texture of peeled products while achieving a similar ease of peeling. At a microscopic scale, the IR thermal effects were characterised by the melting of extracellular cuticles, collapse of surface cellular layers, thermal expansion and then severe degradation of cell wall structures, which essentially increased the peel stiffness and reduced the peel adhesiveness (Li, Pan, Atungulu, Wood, & McHugh, 2014; Li, Pan, Atungulu, Zheng, et al., 2014). All these findings demonstrated the promising potential of IR dry-peeling as a sustainable technology for the peeling of tomato and other vegetables. Over the past decade, much effort has been dedicated to developing different alternative peeling methods such as enzymatic peeling, ultrasonic peeling, and peeling using ohmic heat (Baker & Wicker, 1996; Duplex, 2013; Emadi, 2005; Rock et al., 2011; Toker & Bayndrl, 2003; Wang, Li, Sun, Li, & Pan, 2014; Wongsangasri, 2004). Although attractive and environmentally friendly peeling methods have been increasingly investigated, successful commercialisation of any of the emerging technologies has not yet been fulfilled. Technical barriers, low throughputs and high processing costs have persisted with some technologies, but infrared peeling appears to hold

promise for commercialisation. A pilot scale study is a prerequisite prior to the adoption of subsequent full-scale system.

The specific objectives of this study were to (1) design and construct a prototype IR dry-peeling system for tomatoes; and (2) evaluate the performance of each section of the IR dry-peeling system and the overall peelability as well as the quality of peeled products.

2. Design of IR dry-peeling system

The pilot scale IR dry-peeling system was manufactured by Precision Canning Equipment Inc. (Woodland, CA) and consisted of three major sections: IR heating, vacuum, and a pinch roller section (Fig. 1). The IR heating section is used to loosen tomato skin from flesh and generate cracks through rapid IR heating. The primary function of the vacuum section is to fully create cracks on the tomato surface so as to facilitate the subsequent peel removal. In the third section, the loose skins are removed by mechanical pinch rollers in conjunction with installed air blades using compressed air. The vacuum and pinch roller sections are similar to the systems commonly applied in the tomato industry. Key parameters underlying the design are primarily drawn from our previous experimental and mathematical modelling studies (Li & Pan, 2014b; Li, Pan, Atungulu, Zheng, et al., 2014). Each section is described in details below. The system is mounted on a portable frame that is made of tubular stainless steel 304. All the bearings, motor, controls, sprockets, and chains are similar to the ones currently used in the cannery industry. The system has guards and devices to ensure personnel safety.

2.1. IR heating section

IR heating section is the most critical unit in the dry-peeling process. The dimensions of the heating section are 0.914 × 0.305 m. The IR heating unit is equipped with 9 ceramic IR emitters with curved shape, powered by electricity,

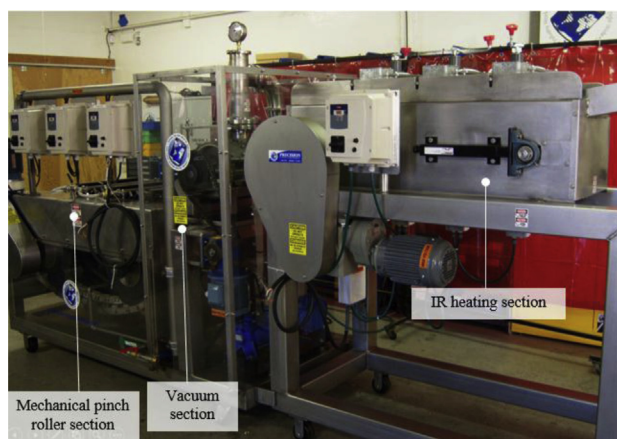


Fig. 1 – Main sections of the pilot scale infrared (IR) dry-peeling system for tomatoes.

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