CALCIFICATION OF DICED TOMATOES BY LIQUID DIPPING VERSUS ELECTROSTATIC POWDER COATING

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ABSTRACT

Diced tomatoes are commonly dipped in calcium solutions to increase their firmness and drained weights. Electrostatic powder coating may be an alternative method to evenly distribute calcium without wastewater production. The objective of this study was to determine if electrostatic powder coating would be as effective as liquid dipping for applying calcium to diced tomatoes. Tomato dices were dipped in a calcium solution for 0–240 s or powder-coated electrostatically with 0–500 mg/kg calcium. Drained weight and firmness increased with dip time and amount of calcium added for both methods. The diced tomatoes that were powder-coated electrostatically with calcium were firmer than the diced tomatoes dipped in calcium solution with the same final calcium content. Drained weights were not significantly different between the two treatments. Electrostatic powder coating could be used in the tomato processing industry to produce optimum firmness at lower calcium concentrations compared to liquid dipping.

INTRODUCTION

Tomatoes soften and break up during processing. Loss of tissue integrity is a problem in the processing of diced tomatoes, where the diced tomatoes are subjected to high temperatures during thermal processing and shear stress through pumps, strainers, pipes, fillers and tanks (Gould 1992). These processed diced tomatoes are later reprocessed to make high-value end products.

Texture is an important quality characteristic, along with drained weight. Tomatoes are therefore processed with calcium salts to improve the texture of the final product (Gould 1992). Firmness and resistance to softening induced

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by divalent calcium ions are attributed to the formation of calcium pectate or pectinates by binding pectin methylesterase – demethoxylated pectate chains, which increase the rigidity of the middle lamella and cell wall (Grant *et al.* 1973). Calcium pectate also results in increased resistance to polygalacturonase attack of the pectic substances of the middle lamella, cell wall and the pericarp tissue in general (Buescher and Hobson 1982).

Two methods of applying calcium are used in the industry. One method is the direct addition of calcium to individual cans. Commercially available tablets are added to the can before retorting, or powder is dissolved in the cover juice. The second method is the dipping of diced tomatoes into a solution containing calcium before further processing. This is more common because it is used for the aseptic processing of diced tomatoes, which is the majority of the market.

Studies have examined the optimum conditions for calcification of diced tomatoes by liquid dipping. A low-calcium concentration (0.43% $CaCl_2$) at 35C for 3.5 min gave tomato dices with a calcium content below the legal limit of 800 ppm, maximum firmness and a pH low enough to eliminate any additional acidification treatment for raw diced tomatoes (Floros *et al.* 1992). In another study, it was concluded that a contact time of 1 min in a 0.75% calcium dip solution at $<$40C gave optimum calcium uptake, drained weight and sensory attributes for canned diced tomatoes (Porretta *et al.* 1995). However, powder coating studies have not been published.

For application of calcium, powder coating could be an alternative to liquid dipping method. The absence of dip solutions would eliminate the problems with wastewater treatment and reduce the amount of water used for the process. Any oversprayed powder can be collected and recirculated to increase the overall efficiency of the process. The use of electrostatic powder coating gives more uniform coating and lower dust formation than nonelectrostatic coating because the electrostatic charge on the powder causes it to spread out across the target and seek the nearest ground rather than stay suspended in air as dust (Anon 1996). The objective of this study was to evaluate electrostatic powder coating as a possible application method for calcium by comparing dice firmness and drained weight to that produced by the liquid dipping method.

MATERIALS AND METHODS

Processing tomatoes (cv. P696) for this study were mechanically harvested in Fremont, OH. The tomatoes were soaked in an air-agitated washer and conveyed to lye bath for peeling. The lye concentration was 18% NaOH along with a wetting agent, 0.1% Faspeel (BASF Wyandotte Corp, Wyandotte, MI). Time of peeling was 30 s at 87.8C. The lye bath was followed by washing under a low-pressure spray on a rotary revolving rubber disk belt, which removed the peel. The tomatoes were hand-peeled to remove any remaining peel and sorted for integrity before dicing. An Urschel model GK (Valparaiso, IN) was used for dicing the tomatoes into $1.27 \times 1.27 \times 1.27$-cm cubes. The diced tomatoes were divided into batches to be used for the treatments. The entire experiment was performed in duplicate on different days.

Immediately after dicing, nine 3-kg batches of tomatoes were weighed out. Immersion solution was prepared with a calcium chloride concentration of 600 mg/L in water. The batches of diced tomatoes were dipped into 7 L of calcifying solution at 22C for 0–240 s. Fresh solution was used for each dip. After calcium treatment, the tomato dices were drained for 1 min.

For powder coating, diced tomatoes were coated using an electrostatic powder applicator (Terronics Development Corporation, Elwood, IN) at 25 kV. The conveyor belt was not used for the experiment. Tray position was fixed on the grounded conveyor to produce reproducible amounts of calcium added. The powder was fed directly into the brush feeder, delivered into the injector and fluidized by pressurized air. Pneumatically conveyed powder was passed beneath two negatively charged wires at 25 kV. The powder picked up negative charge in the corona zone before coating the diced tomatoes.

The diced tomatoes were coated with calcium at 0–500 mg/kg. As the amount of calcium used was insufficient for feeding and fluidized in the coater, sodium chloride was used as a carrier agent to aid fluidization. The total amount of powder fed into the coater was 5 g. Nine hundred grams of diced tomatoes was spread out on a tray and electrostatically coated per batch. Two 900-g batches were used for each concentration, and were mixed together after coating. The addition of NaCl has no effect on the firmness or drained weight of canned tomatoes (Siegel 1938; Godfrey 1940; Kertesz *et al.* 1940).

Half of the diced tomatoes for each treatment variable were filled into 300×407 cans manually, with approximately 300 g of diced tomatoes per can. The cans were solid-packed and sealed with steam. They were retorted at 104.5C for 30 min and cooled with cold water to 37.8C for 30 min. The cans were stored at room temperature for 45 days until texture, drained weight and calcium content analyses. The other half of the diced tomatoes were used immediately for firmness testing.

Firmness was measured using a Universal traction–compression machine (Instron 5542, Instron Corporation, Canton, MA) with computerized data acquisition (software Instron series 9, version 5.23) equipped with a 500-N load cell, using a five-blade Kramer shear cell. Measurements were made in triplicate on 100 g of drained diced tomatoes. A 60-mm/min compression rate and a 95-mm dice layer thickness was used. The firmness was recorded as the maximum peak force (N) achieved during shear compression and extrusion.

The drained weight was determined on the canned tomato dices using the standard method in the Federal Food, Drug and Cosmetic Act 21CFR 155.190 (FDA 2003).

The calcium content in the final diced tomatoes was determined by atomic absorption spectroscopy with a Perkin Elmer model 1100 (PerkinElmer Life and Analytical Sciences Inc., Boston, MA) after sulfonitric mineralization on 10 g of sample. The samples were analyzed by the spectrometer using an air-acetylene flame, and measurements were made at a wavelength of 422.7 nm for calcium. All measurements were made in triplicate.

Analyis of variance was used to find differences in response to treatment. Matched pair analysis was used to compare raw versus canned diced tomatoes and liquid dipping versus electrostatic powder coating. Variables are said to be significantly different at $P < 0.05$.

RESULTS AND DISCUSSION

Measured calcium content increased with increasing immersion times in the calcium bath (data not shown). The increase in calcium concentration with increasing dip time was also observed by Floros *et al.* (1992), Porretta *et al.* (1995) and Villari *et al.* (1997). The diced tomatoes that were electrostatically powder-coated showed a similar increase in measured calcium content with increasing calcium addition (data not shown). For both liquid dipping and powder application, calcium diffuses from the surface of the diced tomato toward the center because of osmotic pressure. Inside the tomato, the calcium forms bridges between chains of deesterified galacturonic acid residues on pectin by bonding with the free carboxyl groups, increasing the cell-cell adherence. This increased firmness and absorbed calcium.

If electrostatic powder coating produced tomato dices comparable in texture and calcium content to the liquid dip method, then it could be a possible alternative to the traditional immersion process. Reduction in water usage by eliminating dip solutions, and the subsequent reduction in wastewater would be a significant improvement in the calcification process. To determine the effectiveness of this process, the firmness produced by electrostatic powder coating of diced tomatoes was compared with the immersion in calcifying bath on the basis of equivalent calcium absorbed (Fig. 1). Electrostatic powder coating produced diced tomatoes with significantly firmer texture at the same measured calcium content as liquid dipping for both raw and canned diced tomatoes.

An effect of addition method on firmness is shown in other studies as well. Immersion in a calcium bath gave tomatoes with lower measured calcium content the same firmness compared to direct calcium addition to the can

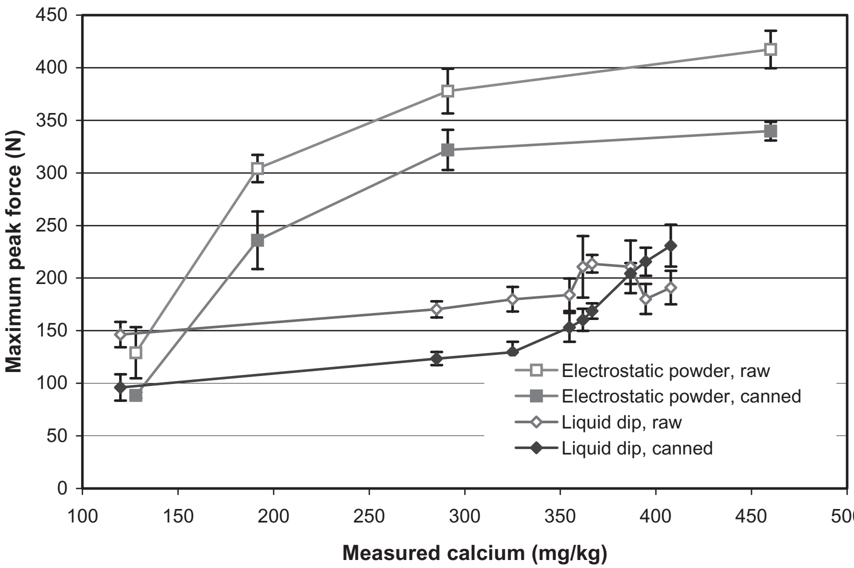

FIG. 1. FIRMNESS OF DICED TOMATOES TREATED BY LIQUID DIPPING AND ELECTROSTATIC POWDER COATING

(Castaldo *et al*. 1995; Villari *et al*. 1997). In those studies, adding calcium directly into the can may not distribute the calcium uniformly, hence preventing the tomatoes from absorbing the maximum amount of calcium, while liquid dipping uniformly exposes the tomato dices to the calcium. Electrostatic powder coating also gives a uniform coating layer on the product (Clark 1995; Hanify 2001), thus allowing calcium to diffuse evenly into the diced tomatoes. The even layer of coating ensured that the coating diffused evenly through the diced tomatoes, and formed cation bridges systematically throughout the tomato tissue.

It is unclear why powder coating produces a firmer diced tomato than liquid dipping. Calcium applied as a powder dissolves only in the water on the surface of the tomato. This creates a high local concentration on the surface of the tomatoes, which in turn creates a large osmotic pressure that may have increased the diffusion so that the calcium diffuses deeper toward the center of the dice than in liquid dipping, increasing the firmness on the entire tomato dice rather than just on the surface.

The firmness of raw and canned diced tomatoes (liquid-dipped and powder-coated) increased with calcium concentration as expected (Fig. 1). The canned tomato dices were significantly softer than the raw tomato dices for both liquid dipping and powder application. Thermal processing damages

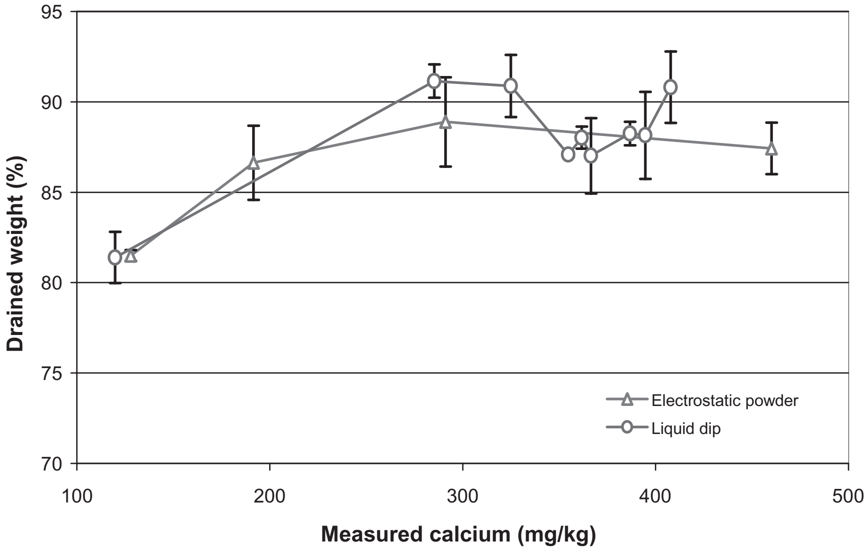

FIG. 2. DRAINED WEIGHTS OF DICED TOMATOES TREATED BY LIQUID DIPPING AND ELECTROSTATIC POWDER COATING

cell walls and decreases the hydrostatic pressure responsible for maintaining cell turgor in fruit tissue, causing texture loss in canned tomatoes (Bourne and Comstock 1986; Bourne 1989).

The drained weight of liquid-dipped and powder-coated tomato dices significantly increased with dip time (Fig. 2). There was a 10% increase in drained weight up to 300 mg Ca/kg. Any further increase in calcium did not have any significant effect on the drained weight. The results between the two treatments were not significantly different. Villari *et al*. (1997) reported that the drained weight obtained by direct calcium addition was lower than that obtained by immersion in a calcium bath.

Bellucci *et al*. (1975) and Villari *et al*. (1997) observed a similar trend in drained weight. They reported a small increase in drained weight with increase in treatment time and calcium concentration. During thermal processing, juice tends to be squeezed out of the tomato (Castaldo *et al*. 1996), decreasing drained weight. In tomatoes with high firmness values, less squeezing of the tissue occurs and, hence, drained weight increases (Castaldo *et al*. 1996). Also, processing causes the loss of uncalcified locular tissues in the diced tomatoes, which decreases the drained weight. Calcium treatment may improve binding of the locular tissue to the pericarp (Davies and Hobson 1981; Ma and Barrett 2002).

CONCLUSIONS

The addition of calcium by liquid dipping and electrostatic powder coating were both effective in increasing the firmness, drained weight and calcium content of the tomato dices. Electrostatic powder coating produced diced tomatoes that were firmer, with the same calcium concentration as obtained by liquid dipping. Drained weight was not affected by the calcium application method. With electrostatic powder coating, it may be possible to use less calcium without compromising the texture of the diced tomatoes.

Further work is necessary to explore the feasibility of the electrostatic powder coating process to prove if it would be economical in the tomato processing industry. A study of the powder properties of different calcium sources and coating systems is required. However, this study demonstrates that powder coating is potentially equal to or better than the liquid dipping system for applying calcium to tomato dices.

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