Modified pressure imaging for egg crack detection and resulting egg quality

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ABSTRACT Cracks in the shell surface compromise the primary barrier for external microbial contamination of the egg. Microcracks are very small cracks in the shell surface that are difficult to detect by human graders. New technology has been developed that uses modified pressure and imaging to detect microcracks in eggs. Research has shown the system to have an accuracy of 99.6% in detecting both cracked and intact eggs. A study was undertaken to determine if quality differences existed between modified pressure imaged and control eggs during extended cold storage. Three replicates were conducted with eggs stored at 4°C for 5 wk with weekly quality testing. The physical quality factors monitored were Haugh units, albumen height, egg weight, shell strength, vitelline membrane strength and elasticity, and whole egg total solids. All measurements were conducted on individual eggs (12/treatments per replicate) each week with the exception of whole egg solids, which were determined from 3 pools (4 eggs each)/treatment per replicate each week. Percentage of whole egg total solids was the only significant difference (P < 0.05) between treatments (23.65% modified pressure imaged and 23.47% control). There was a significant difference (P < 0.05) for egg weight between replicates (60.82, 58.02, and 60.58 g for replicates 1, 2, and 3, respectively). Therefore, imaging eggs in the modified pressure system for microcrack detection did not alter egg quality during extended cold storage. Utilizing the modified pressure crack detection technology would result in fewer cracked eggs reaching the consumer, consequently enhancing food safety without affecting product quality.

Key words: shell egg, crack, detection, imaging, quality

INTRODUCTION

The shell is one of the first lines of defense of an egg from external bacterial contamination. Eggs with cracks in the shell surface pose greater food safety risks for consumers than intact eggs (Todd, 1996). Furthermore, researchers have found a wide variety of bacteria in the contents of eggs with cracks in their shells (Ibeh and Izeagha, 1986; Widdicombe et al., 2009). Challenge studies have determined that Salmonella Enteritidis, as well as Campylobacter jejuni, can penetrate, sustain, or grow in the contents of eggs with cracked shells (Chaudhary et al., 1989; Ernst et al., 1998; Hara-Kudo et al., 2001).

Large cracks in the shell can easily be seen with the human eye or enhanced with illumination in hand candling. Microcracks in the shell, as defined by Bain et al. (2006), are much more difficult to detect. Microcracks are minute cracks in the shell surface (external or internal) that reduce the protective barrier properties of the shell. Studies confirming (via scanning electron microscopy) the presence of microcracks in the shell surface have also found greater bacterial penetration in eggs with a higher number of microcracks (Fajardo et al., 1993, 1995). Microcracks are not easily seen by the human eye.

All shell eggs marketed in the United States may have a maximum allowable percentage of checked eggs (shell impaired with no egg contents voiding) ranging from 5 to 10% in a grading lot of 100 eggs (USDA, 2000). The actual percentage of checked eggs allowed is variable for the stage of commerce and US egg grade. Traditionally, hand candling with various forms of illumination is used by professional graders to ascertain if cracks are present in the egg shell, which limits the ability to see very small microcracks. Professional egg graders are able to quickly assess a 100-egg lot, but the subjective nature of the process leads to variability between graders.

Researchers have worked to develop objective methods for determining shell soundness, thus increasing the microbial safety of eggs reaching consumers. Staining eggs to visibly detect cracks in the candling booth of processing lines has been tested (Dickens et al., 2010).
Elster and Goodrum (1991) used machine vision to detect sizable eggshell cracks. Dynamic frequency analysis was used for crack detection and sorting by Wang and Jiang (2005). In some instances, developed technologies were assessed for their degree of detection accuracy: global image analysis, 88% (Han and Feng, 1994); machine vision with different light sources, approximately 90% (Worley and Goodrum, 1995); and acoustical resonance frequency, 90% (De Ketelaere et al., 2000). Bain et al. (2006) assessed the microscopic formation of microcracks. They determined that the nature of microcrack formation made it unlikely that online crack detection in shell egg processing equipment would find microcracks because the technology is based on mechanical excitation.

United States consumer eggs are monitored via hand candling to ensure food safety and quality standards have been met. Human graders experience fatigue from extended hours in darkened rooms with a concentrated light source. The fatigue can impair the grader’s ability to consistently assess eggs. During a study examining candling errors in commercial egg processing, 17.3% of pulled eggs were overpull (Bokhari et al., 1995). Of the overpull, 42.5% was due to cage marks on the shell. As a crack in the shell ages, water migrates to the crack causing it to glow during candling much like cage or toenail marks. Fresh microcracks are almost impossible to detect visually. If the eggs are placed in refrigerated storage overnight, the microcracks become more visible due to physical changes such as water migration and entrapment between the shell and shell membranes or enlargement due to thermal stress on the shell during cooling. With the current industry standard of high-throughput machines and inline complexes, it is not plausible to regrade lots of eggs 24 h after processing. A novel system for crack detection utilizing modified pressure and imaging has been developed (Lawrence et al., 2008). The system conditions allow for large and microcracks alike to be seen by subjecting the eggs to a quick, small negative pressure while digital images are collected. The system is designed to be operated by a professional grader, thus allowing for crack detection and quality attribute assessment to occur simultaneously. The modified pressure imaging system had an overall accuracy of 99.0%, compared with 94.2% for trained professional graders in a study comparing 1,000 eggs (Lawrence et al., 2009). The current study was undertaken to determine if exposure to the modified pressure imaging system produced egg quality changes during extended cold storage.

**MATERIALS AND METHODS**

**Egg Sampling**

Three 30-dozen cases of grade A large white eggs were removed from the processing line after packaging at a local inline egg processor. The eggs were processed under the voluntary shell egg grading program with continuous USDA Agricultural Marketing Service inspection (USDA, 2008). Each 30-dozen case (360 eggs minus cracked eggs) was considered a replicate with 15 dozen imaged and 15 dozen controls. All eggs were stored at 25°C overnight and hand candled to remove visible cracks before initiating the experiment.

**Imaging of the Eggs**

Approximately 15 dozen eggs from each case (replicate) were exposed to the modified pressure crack detection system. The basis of the crack detection system is described by Lawrence et al. (2008). The system used in the current study is a modified version of the Lawrence et al. (2009) system. The primary difference between the 2 systems is the 20-egg capacity in the current study (Figure 1). All imaged eggs were exposed to 4 pressure modifications consisting of an approximately 0.5-s exposure to an ~200-mm mercury-negative pressure, as described by Lawrence et al. (2008). Any cracked eggs discovered during imaging were removed from the experiment. The untreated control eggs were moved to the imaging room to maintain consistent temperature conditions between the treatments. After imaging, treated and control eggs were placed in clean foam cartons (Dolco Packaging Corp., Lawrenceville, GA) and eggs from a single replicate were stored in the same cardboard case (Dahlonega Packaging Inc., Dahlonega, GA). All eggs were stored at 4°C for the remainder of the study.

**Egg Quality Determination**

Egg quality testing was conducted weekly from 0 to 5 wk of cold storage. Week 0 testing was conducted the morning after imaging was concluded. Eggs remained under refrigeration until testing and were hand candled to remove cracked eggs. A 12-egg sample for each treat-