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Surface pasteurisation of shell eggs

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Abstract

Microbial and visual contamination of eggs during production and processing is of concern to the consumer and to the egg industry for both health and economic reasons. While egg washing has the potential to reduce significantly the amount of visual and microbial contamination of eggs, there are substantial concerns as to the effectiveness of current egg washing technology. It is also unclear whether the use of egg washing results in salmonella moving from the exterior of the egg shell through the shell into the contents of the egg where they may grow to high levels. A short investigation was carried out on the applicability of four different heat treatments (hot air, hot water, infra-red radiation, and atmospheric steam) for the surface pasteurisation of shell eggs. The aim of this work was to assess temperatures on the outside and interior of the shell to identify the highest surface temperatures that could be achieved without damaging the contents of the egg. Initial results show that temperatures sufficient to achieve significant reductions in salmonella numbers can be attained on the outside of an egg without raising interior temperatures to those that would cause coagulation of the egg contents.

Keywords: Decontamination; Steam; Hot air; Hot water immersion; Infra-red

1. Introduction

Pathogens, especially salmonella, on and in eggs are of major concern because of their influence on food safety. Developments in poultry rearing have lead to a decrease in the incidence of salmonella but they still present a significant food poisoning risk. The vaccination of breeding and laying hens against *Salmonella enteritidis* in the last few years in the UK appears to be largely responsible for the recent fall in the numbers of human salmonellosis cases from a peak of 32,500 in 1997 to 17,000 in 1999 (Anon., 2000). This has reduced the risk of intrinsic contamination. However, the risk posed by exterior contamination remains.

While the washing of eggs is carried out as standard in North America the practice is not permitted at present in the EU for Class 'A' eggs (the class most commonly found at retail). The general reasoning for this is that it is "considered preferable to produce a clean, quality egg in the first place" (MAFF, 2000). However, microbes, including pathogens, can be present in high numbers even on visibly clean eggs. A number of studies have been published on the use of low temperature (< 60 °C) water bath pasteurisation processes to fully pasteurise whole shell eggs and a commercial system has been developed (Hou, Singh, Muriana, & Stadelman, 1996; Schuman, Sheldon, Vandepopuliere, & Ball, 1997; Stadelman, Singh, Muriana, & Hou, 1996). However, by nature this process takes a long time and can result in some detrimental changes to quality and properties of the egg contents. If intrinsic contamination is reduced or eliminated via better vaccination programmes and husbandry, then treatments need only be applied to the exterior of the egg. There have been many studies in recent years into methods of surface pasteurising a range of raw foodstuffs, particularly red meat, using hot water and steam (James & James, 1998). A few studies (Gast, 1993; Himathongkham, Riemann, & Ernst, 1999) have investigated the applicability of hot water treatments for surface pasteurising shell eggs, with some success.

The purpose of the work presented here was to carry out a short investigation into the applicability of four different heat treatments (hot air, hot water, infra-red, and atmospheric steam) that had previously been applied on other foodstuffs for the surface pasteurisation of shell eggs. The aim of this work was to assess temperatures on the outside and interior of the shell to

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identify the highest temperatures that could be achieved on the outside of eggs without damaging the contents of the egg or the shell itself.

2. Materials and methods

2.1. Shell eggs

UK standard, class 'A' free-range eggs were obtained from a local farm shop. The average length, width (widest point) and weight was 58.6 mm (1.8 SD), 44.6 mm (0.9 SD), and 66.4 g (2.9 SD), respectively. The average shell thickness was 0.38 mm (0.03 SD).

2.2. Egg simulants

In order to measure external and internal surface temperatures on either side of the egg, shell simulants were constructed by filling empty egg shells with general purpose epoxy resin (RS 199–1468, RS Components, Northants, UK; ratio of 1:1, density (g/cm^3) 1.06, thermal conductivity (W/m°C) 0.377, operating temperature range (°C) −50 to +120). A 15 mm diameter hole was cut through the shell of the egg (at the pointed end of the egg) and the contents removed (including the inner and outer membranes). The empty shell was then carefully rinsed with water and dried. A K-type (Chromel–Alumel; 0.003 mm diameter) thermocouple was attached to the inside of the shell using resin. The whole shell was then filled with 60 g of the resin and left to harden for 24 h. A K-type thermocouple was then attached to the outside of the shell adjacent to the interior thermocouple using the resin. Temperatures were recorded every second using a Squirrel meter/logger (1000 series, type 1005, Grant Instruments (Cambridge), UK).

2.3. Hot air apparatus

Hot air was produced using a 'hot air gun' (Power Devil PDW 5001, 1500 W). This hot air gun had two heat settings: 300 and 500 °C. In operation, the gun was switched on for 1 min before exposing the egg to allow the air temperature to equalise. The first and second series of experiments showed that the eggs had to be at least 150 mm from the heat nozzle and exposed no more than 8 s with the heat setting at 500 °C to prevent over heating. Longer treatment times at 150 mm or shorter distances damaged the shell or partially cooked the egg contents. Greater distances between the gun and the egg surface required substantially longer treatment times to reach sufficiently high temperatures on the outside of the shell.

2.4. Hot water apparatus

Eggs were immersed by-hand into a heated water-bath (20 l, LTD 6/20, Grant Instruments (Cambridge), UK).

2.5. Infra-red apparatus

A domestic multifunction oven with two medium wavelength infra red quartz tubes (Selection Magimix, Type MR26) was used in this experiment. The oven was operated for 10 min to equalise the cavity temperature before treating the eggs. The first and second series of experiment showed that the most suitable treatment was obtained when the thermostat was on setting 10 (225–250 °C) with no bottom heating element, switch set to 0 during 30 s.

2.6. Steam apparatus

An experimental rig was constructed using a simple steam generator (Wallpaper striper 5 l, model SS76, Wickes, UK) feeding via two plastic pipes (40 mm diameter) and distributors into a plastic cylindrical chamber (190.5 mm length, 114.3 mm diameter, 2 mm thick). The eggs were placed in a clamp stand and treated by manually lowering the steam chamber over the egg and stand for the required time.

2.7. Cooling

All eggs/simulants were left to cool after treatment in ambient air in an environmentally controlled room with a constant room temperature of 20 ± 1 °C.

2.8. Experimental protocol

Three series of trials were conducted. In the first series, egg simulants were subjected to a series of time/temperature treatments for each heating process to determine the maximum time that the eggs could be subjected to without raising the interior temperature above 60 °C. One time/temperature treatment was identified for each heat process.

These four time/temperature treatments were then tested using whole shell eggs. Five eggs were subjected to each heat process. All eggs were examined subjectively for any visible damage on the shell and each egg broken into clear vessel and visually assessed for signs of coagulation.

A final series of experiments was carried out to measure accurately the temperature outside and inside the eggshell for each heat process. Five trials were conducted for each heating process tested using one resin filled egg.

Table 1
Time/temperature treatments

Treatment	External 'air' temperature (°C)	Exposure time (s)
Hot air	180	8
Hot water	95	10
Infra-red	210	30
Steam	100	2

3. Results

Time/temperature treatments identified in the initial trials are shown in Table 1. Whole eggs subjected to these treatments showed no visible damage to the shell or visible signs of coagulation of the white.

Mean temperature/time plots recorded using egg simulants for each of the four heat processes are shown in Fig. 1 (hot air), Fig. 2 (hot water), Fig. 3 (infra-red) and Fig. 4 (steam). Average maximum external surface temperatures were 85 (S.D. 13), 86 (S.D. 5), 88 (S.D. 2),

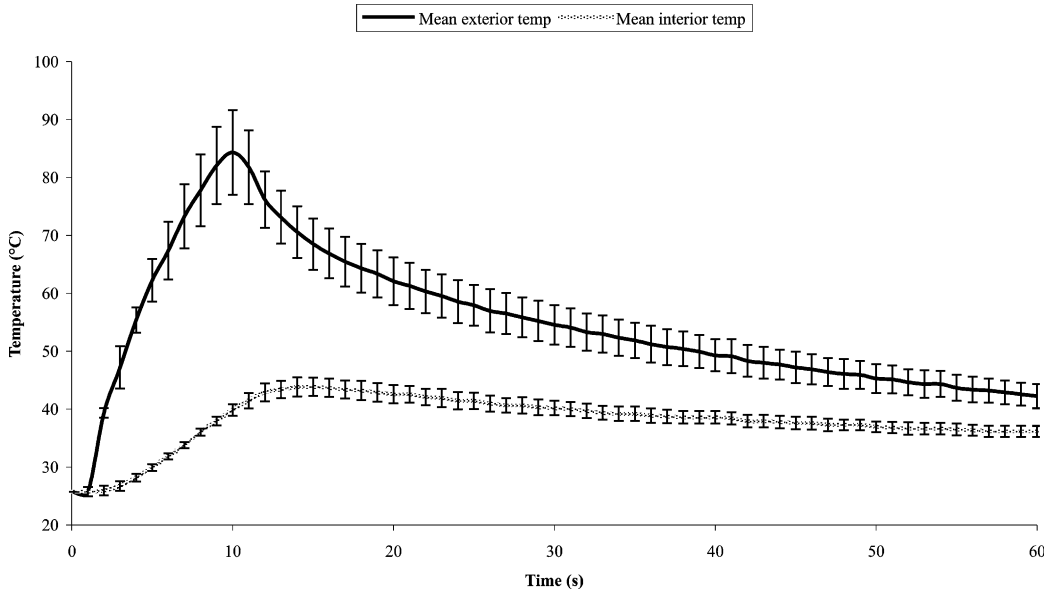

Fig. 1. Temperature plots of mean ($n = 5$) exterior and interior temperatures on the shells of eggs subjected to hot air (180 °C) for 8 s.

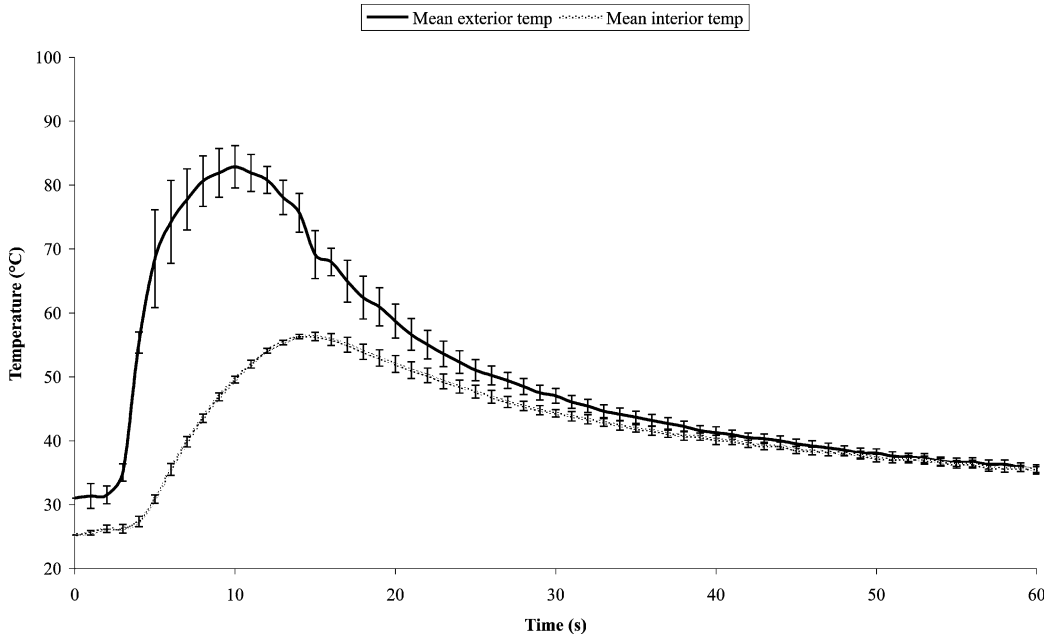

Fig. 2. Temperature plots of mean ($n = 5$) exterior and interior temperatures on the shells of eggs subjected to hot water (95 °C) for 10 s.

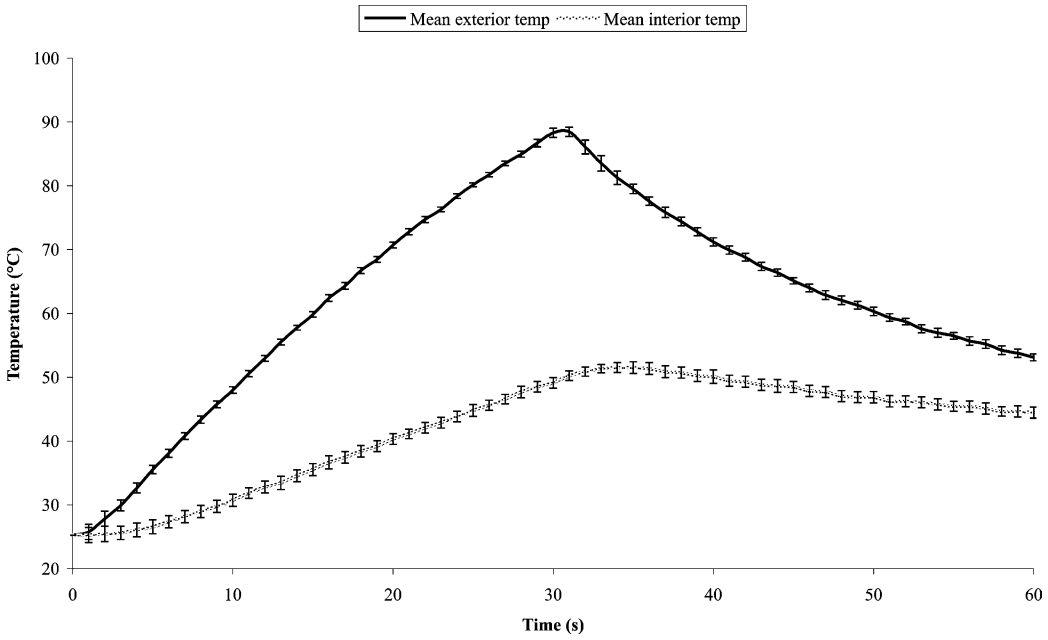

Fig. 3. Temperature plots of mean ($n = 5$) exterior and interior temperatures on the shells of eggs subjected to infra-red exposure (210 °C) for 30 s.

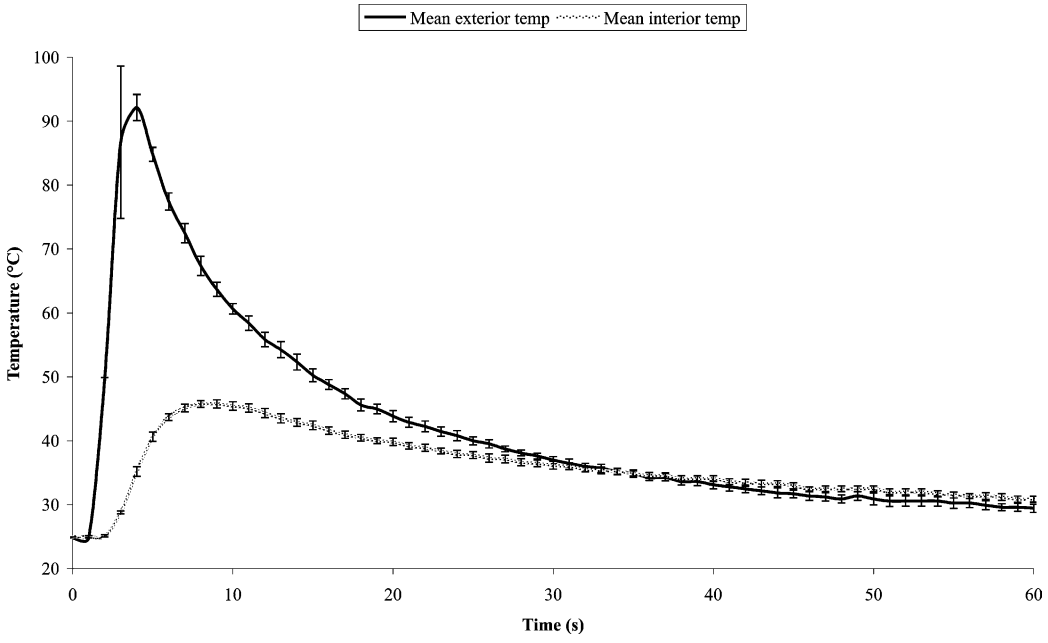

Fig. 4. Temperature plots of mean ($n = 5$) exterior and interior temperatures on the shells of eggs subjected to steam (100 °C) for 2 s.

92 (S.D. 2) using hot air, hot water, infra-red and steam, respectively. Average maximum internal surface temperatures were 44 (S.D. 3), 57 (S.D. 2), 52 (S.D. 2), 46 (S.D. 1) using hot air, hot water, infra-red and steam, respectively.

4. Discussion and conclusions

The results show that temperatures sufficient to achieve significant reductions in bacterial numbers can be attained on the outside of an egg without raising interior temperatures to those that would cause coagulation of the egg contents. The water immersion trials showed that at 95 °C eggs could be subjected to the conditions for as long as 10 s. Himathongkham et al. (1999) reported that dipping eggs for 3 s in boiling water resulted in complete destruction of *S. enteritidis* in shells and membranes, but sometimes caused eggs to crack. No problems of egg cracking were encountered under any of the treatments during the experiments reported here. However, only a small number of samples were

used in experiments in this paper. Since egg shells are not uniform it is possible that a higher number of samples could also lead to signs of egg cracking. Thermal inactivation data for *S. enteritidis* ATCC 13076 in liquid whole eggs were published by Muriana, Hou, and Singh (1996). Their data shows *D*-values of 16.5 min at 50 °C and 0.7 min at 57.5 °C. Extrapolating these values would indicate that temperatures of over 70 °C for less than 1.5 s should be capable of reducing *S. enteritidis* populations by as much as 6 log. If this is so, all of the treatments investigated are theoretically capable of reducing salmonella numbers on the exterior surface of an egg shell by 6 log without adversely damaging the interior contents. However, it is likely that the heat resistance of cells on the exterior surface of an egg would be different to those in contents of the egg. There is also known to be a difference in the resistance of bacteria to 'wet' or 'dry' heat treatments.

Further investigations need to be carried out to assess the actual effect of such treatments on external bacteria. There is also the possibility that such treatments may cause damage to the shell and/or cuticle, increasing the risk of extrinsic contamination becoming intrinsic contamination. Microscopic investigations are required to assess possible alterations to the surface after treatments. In addition, this short investigation only focused on the coagulation of the egg content. Other quality parameters, e.g. physical consistence of egg white and egg yolk, and the effects of the treatments on the protein structure need to be further assessed. These issues aside, the data presented herein demonstrate the potential use of heat treatments to pasteurise the surface of eggs.

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