A study on effect of immersion heat treatment on viability of *Salmonella enteritidis* in table eggs.

BY

ZIENAB I.SOLIMAN and AZZA A. EL-TABIY

Animal Health Research Institute, DOKKI

Port Said Laboratory for Food Hygiene.

دراسة تأثير المعالجة الحرارية بالغمر على حيوية ميكروب السالمونيلا انتريتدس فى بيض المائدة

زينب إبراهيم سليمان، عزة على حسين التابعى

يعتبر البيض من أهم العناصر الغذائية التي تدخل في العديد من أصناف الطعام والحلويات٠ ولما كان البيض النيئ يستخدم في تحضير بعض أصناف من الطعام مثل المايونيز والمارنج والأيس كريم والذي قد يؤدى إلى العدوى بميكروب السالمونيلا انتريتدس وخاصة أن معظم الدراسات تشير أن هناك ارتباط وثيق بين تناول البيض النيئ والغير مطهو جيدا والإصابة بذلك الميكروب٠ لذلك يهدف هذا البحث لدراسة تأثير غمر البيض فى حمام مائى بدرجات حرارة مختلفة على حيوية ميكروب السالمونيلا انتريتدس ٠ لذا تم حقن البيض بميكروب السالمونيلا انتريتدس (١٠^{٧} خلية/ جم) قرب المح وتم استبيان اثر غمر البيض فى حمام مائى بدرجات حرارة تتراوح بين ٥٧-٥٩ درجة مئوية على حيوية الميكروب وذلك على فترات أثناء الغمر٠ وقد تبين أن هناك نقص تدريجيا في العدد الكلى لميكروب السالمونيلا انتريتدس أثناء الغمر ويتوقف ذلك على عاملي درجة الحرارة ومدة الغمر٠ هذا وقد تم القضاء على الميكروب كليا بعد ٧٠و٥٥ و ٤٥ دقيقة من الغمر فى درجات حرارة ٥٧و ٥٨ و٥٩ درجة مئوية على التوالى ولم يكن هناك تغير ملحوظ ظاهريا فى الشكل الخارجى للبيض المعالج بالغمر عن البيض الذى لم يتم غمره ٠ كذلك تم دراسة اثر التعرض لمختلف درجات الحرارة أثناء المعالجة

الحرارية بالغمر على الخصائص الطبيعية والوظيفية لزلال البيض وقد تبين من الدراسة أن المعالجة الحرارية بالغمر عند درجة ٥٧ درجة مئوية كان له تأثير اقل فى أحداث تغير في الخصائص الطبيعية لزلال البيض مقارنة بالمعالجة فى درجات حرارة ٥٨ و ٥٩ درجة مئوية٠ كذلك وجد انه يلزم زيادة الوقت اللازم لخفق بياض البيض للحصول على المارنج فى البيض المعالج بالغمر ٠ هذا وتعتبر طريقة المعالجة الحرارية بالغمر طريقة للتخلص من ميكروب السالمونيلا مما يشكل استخدام امن للبيض النيئى الذي يدخل فى العديد من الأطعمة وما له من اثر على الصحة العامة ٠ هذا وقد تم مناقشة الأهمية الصحية وكذلك الاحتياطات التى يجب مراعاتها للحد من خطورة ميكروب السالمونيلا.

SUMMARY

Eggs are a highly nutritious, inexpensive food commodity which is accepted by most people. The safety of eggs has become a global issue with emergence of the pathogen *Salmonella enteritidis* as a major health hazard associated with the consumption of raw and semi-cooked eggs. The effects of water – bath heat treatments on the inactivation of *Salmonella enteritidis* within eggs were evaluated. *Salmonella enteritidis* (10^7 cfu/g, inoculated near the centre of the yolk) was completely eliminated within 70 min at a bath temperature of 57^0C, within 55 min at a bath temperature of 58^0C and within 45 min at a bath temperature of 59^0C. No significance difference in the visual appearance between the control and immersion heated eggs meaning that heated eggs will be seen as normal eggs. In addition, effect of immersion heat treatments on the functional properties of egg white was evaluated. Evidence from the current study confirms that prolonged egg heating at 57^0C for 70 min was effectively eliminate *Salmonella* and produce *Salmonella* free eggs with an acceptable quality. There is no coagulation, or loss in

functionality of egg components. Albumen turbidity and functionality were significantly affected by thermal treatments in eggs treated at 58 and 59^0C and was less affected at 57^0C. Extended whip time would require for meringue preparation using immersion heated egg white. Immersion heat treatment could provide *Salmonella enteritidis* free egg for preparation of food receive little or no heat treatment prior to consumption and thereby combat the risk of Salmonella.

INTRODUCTION

Table eggs are one of the most economic and balanced sources of protein available with cost per kg to consumers lower than chicken or meat in most countries. In addition, eggs contain unsaturated fatty acids, iron, phosphorus, trace minerals, and vitamins **(Stadelman, 1995 and Watkins, 1995).** Due to its exceptional nutritive value, eggs remain a potential host for pathogens like *Salmonella enteritidis*. **Gast and Beard (1992)** suggested that human-salmonellosis outbreaks, related to consumption of eggs, occurred as a consequence of three independent events; (i) contamination of eggs with *Salmonella enteritidis* by infected hens, (ii) improper handling of eggs or egg products allowing proliferation of the microorganism to infectious levels, and (iii) ingestion of raw or undercooked contaminated eggs. It is apparent from the voluminous reports that *Salmonella enteritidis* was more oftenly associated with human foodborne disease outbreaks than other Salmonella serotypes particularly those associated with egg and egg products **(Brackett *et al*., 2001 and Shirota *et al*., 2001).** Unlike others of the 2000 serovars of Salmonella, this organism infects the egg before the egg is laid, with the organism being transmitted to the ova or the albumen before the formation of the shell of the egg **(Humphrey, 1999)**.More than 90 percent of food borne Salmonellosis, caused by *Salmonella enteritidis* is through the shell eggs **(Woodward *et al*., 1997**

and Schroeder *et al.*, 2005). The probability of fresh eggs having Salmonella varies from 0.005 % to 1 **%,** depending on various factors involved in the egg production **(Mermelstein, 2001)**. Food borne Salmonellae are estimated to cause 1.3 million illnesses, 15,000 hospitalizations, and 500 deaths per year (**Schroeder *et al.*, 2005).** Likewise, gastroenteritis is the most common clinical manifestation of the human *Salmonella enteritidis* infection **(Bennasar *et al.*, 2000).**

Generally, Salmonella enteritidis is the causing agent of human gastroenteritis, an infection that results in a clinical syndrome generally known as salmonellosis. Symptoms of gastroenteritic salmonellosis may include severe abdominal pain, non-bloody diarrhea, myalgia, chills, nausea, headache, fever, vomiting, and prostration. In addition, other medical conditions such as pericarditis, neurological and neuromuscular diseases and reactive arthritis may result in some individuals after the infection **(D'Aoust, 1989).** Symptoms occur 12-72 h after consumption of *Salmonella enteritidis* contaminated food, and the infective microbial dose, necessary to cause foodborne illness, varies from □100 cells in high fat foods to 10^5 cells in lower lipid content foods **(Bell and Kyrikiades, 2002)**. The microorganism multiplies and colonizes the small intestine, produces an enterotoxin that causes inflammatory reaction and diarrhea, and in some cases it can invade the blood stream to cause more severe illness **(Poppe, 1999; D'Aoust, 2001and Bell and Kyrikiades, 2002)**. Duration of gastroenteritis syndrome generally varies from 4 to 10 days; during this time, microbial invasion of the small intestine and colon could affect absorption of nutrients in the patient **(Poppe, 1999)**. Moreover, susceptibility of humans to *Salmonella* infections depends on a series of factors that include the dose of the pathogen, the type of contaminated food, and the age and immune condition of the host **(D'Aoust, 1989 and Poppe, 1999)**. The newborn, elderly, and individuals with immune

deficiencies are more susceptible than the rest of the population to infection by *Salmonella enteritidis*. In these groups at risk, salmonellosis could result in serious systemic infections with sporadic cases of death **(D'Aoust, 2001)**. On the other hand, healthy individuals rarely die from salmonellosis, and they normally recover from the disease after treatment with fluid and electrolyte replacement, while antibiotic therapy is not usually recommended in developed countries **(Bell and Kyrikiades, 2002)**.

Eggs are one among the major animals foods mostly marketed raw and frequently consumed raw. Many of the dishes like Caesar salad, mayonnaise, eggnog, mousse, home made ice cream and etc., which form an important part of meals, contain raw eggs as an essential ingredient. These dishes are not heated up to the FDA recommended temperatures of 155ºF for at least 15 seconds **(Mermelstein, 2001)**. Although there are several methods of microbial destruction like rapid chilling and ultrasonic treatments to destroy Salmonella, they are not effective on the Salmonella present inside shell eggs **(Hou *et al.*, 1996)**. So control of *Salmonella enteritidis* within shell eggs has been attempted with a limited number of procedures that include the use of gamma & X-ray radiation and thermal pasteurization **(Tellez *et al.*, 1995; Schuman *et al.*, 1997 and Serrano *et al.*, 1997)**. Public health concerns regarding contamination of fresh eggs with *Salmonella enteritidis* prompted approval of a thermal process to eliminate this microorganism in shell eggs **(USDA, 1997)**. Pasteurization of eggs (in shell pasteurization) is a commercially available process, which consists of extended heating of shell eggs by immersion in water baths at 55-60ºC or by hot air in convection ovens **(Schuman *et al.*, 1997; Brackett *et al.*, 2001 and Zeidler, 2001)**. *Salmonella enteritidis* has been in fact used as sentinel organism for the establishment of pasteurization schedules of processed liquid egg products **(Ponce *et al.*,**

1999). Previous investigators indicated that immersion heat treatments of eggs at 57^0C or above are required to effectively inactivate *Salmonella enteritidis* inside shell eggs (**Hou *et al.*, 1996; Schuman *et al.*, 1997 and Stadelman *et al.*, 1996)**.

The heat treatment of whole shell eggs required balance between reduction of target organisms and the maintenance of albumen quality. The physical properties like whip ability, foam ability and foam stability, affecting the functional properties, which make the eggs an inevitable ingredient of various food products are severely affected by high temperatures **(Iesel *et al.*, 2006).** Whip volume is a measure which gives a clear picture of the quantity of air incorporated in the egg white foam. This is an important factor that tells about the aerating properties of the egg white in its food applications. The commercial use of egg white is highly dependent on its foam ability in many of its applications in the food industry **(McDonnell *et al.* 1955)**.

Therefore, this study investigates the effects of water bath immersion heat treatment at 57^0C, 58^0C and 59^0C on viability of *Salmonella enteritidis* within table eggs. In addition, the impact of the treatment on functional properties of the egg white was assessed.

MATERIALS AND METHODS

Bacterial culture:

Salmonella enteritidis, isolated from eggs, was kindly provided by Animal Health Research Institute, Dokki, Giza. Stock culture was transferred to brain heart infusion (BHI) broth and incubated at 37^0C for 24 h. This concentrated suspension was used to prepare working cell suspension in phosphate buffer. The cell suspension was serially diluted to a concentration of 10^7 cfu/ml.

Preparation of eggs:

Fresh and unfertilized hen shell eggs obtained from local farm, proved to be free from *Salmonella enteritidis* according to methods carried out by **FDA (1998)**, were kept at 4ºC and used within one week of laying. Selected eggs were transferred to trays and then held at 22-25ºC for 2 h. Individual shell eggs were washed with tap water and gently scrubbed with a plastic brush. Clean eggs were submerged in ethanol (70% vol/vol) for 30 min as described previously by **Hammack *et al.*(1993)**. Sanitized shell eggs were immediately transferred to sterile container and permitted to dry at 22-25°C for 40 min before inoculation with *Salmonella enteritidis*.

Inoculation of shell eggs with *Salmonella enteritidis*:

Sanitized eggs were carefully drilled in the approximate center of pointed end of shell eggs (opposite to the air cell) with 5-6 mm sterile needle, placement in close proximity to the yolk **(Chantarapanont *et al.*, 2000)**. *Salmonella enteritidis* cell suspension (10^7 cfu/g) was inoculated into yolk. After inoculation, the hole in the shell was then sealed with a small piece of sterile aluminum foil and super glue. Internally contaminated eggs were immediately placed on sterile trays and incubated at 37^0C for 30 min. After incubation, contaminated eggs were held at 22-25°C for approximately 10 min before heat inactivation trial.

1-Immersion heat treatment inactivation of *Salmonella enteritidis* trails in shell eggs :

Contaminated eggs were placed inside aluminum baskets. Water bath was previously calibrated to attain 57, 58, or 59ºC. Eggs inside basket were heat treated by immersion in water at 57, 58 or 59^0C for 5-70 min. Contaminated untreated shell eggs were used as controls in all experiments. During heat treatments, level of water above shell eggs was 4 cm. Experiments were performed with three shell eggs per time-temperature trial. Three eggs per experimental condition in duplicate series were taken from water bath at selected intervals. Eggs were placed

in 2-liter glass beakers containing 1.5 liters of sterile distilled water at 22^0C. Eggs were held for 10 min in water for cooling. Cooled eggs were gently dry-wiped with clean paper tissue.

1.1- Enumeration of *Salmonella enteritidis*:

Treated or control shell eggs were carefully broken from outside with the blunt end of a clean knife's blade. Egg contents (albumen and yolk) were blended and diluted 1:10 (w/w) with chilled sterile lactose broth. Serial dilutions of this homogenate were prepared in peptone water and 0.1 ml of diluted samples was plated onto pre-poured tryptic soya agar (TSA) plates. Plates were held at room temperature for 3 h and overlaid with tempered (45^0C) xylose lysine desoxycholate agar (XLD; Difco) as described by **Strantz and Zottola (1989)**. The overlay was permitted to solidify at room temperature and plates were incubated at 37^0C for 48h. Black or black centered colonies were enumerated as Salmonella *enteritidis*, and suspected isolates were confirmed by re-isolation onto XLD agar plates (37^0C, for 24 h) and biochemical confirmation in triple sugar iron (TSI; Difco) agar slants (37^0C, for 24 h). At the time of plating into TSA, the remaining blended egg/ lactose broth was retained as enrichment and incubated at 37^0C for 24 h. After mixing, 1 ml of enrichment broth was transferred to 10 ml of Rappaport^s broth (37^0C, for 24 h). The incubated culture was streaked on XLD agar plates and incubated for 48 h at 37° C. Characteristic colonial morphology of *Salmonella* spp. was observed. Presumptive Salmonella isolates were selected and confirmed on TSI slants as previously described.

2-Effect of thermal treatment on albumin quality:

Based on *Salmonella* inactivation data previously recorded, the second experiment was conducted to assess the effect of such treatment on albumen quality and functionality: albumen clarity, pH, whip time and whip volume **(Iesel *et al.*, 2006).**

Sanitized non inoculated eggs were heat treated in water bath at 57, 58, and 59^{0}C for up 70, 55 and 45 min, respectively. Appropriate controls were used in all experiments. Eggs from triplicate trials with a total of ten shell eggs per experimental condition were used. All experiments were performed in duplicate with appropriate controls. Immediately after the above mentioned heat treatments the shell eggs were immersed in cold water tub containing water at 5 ºC for 10 min. Treated and control shell eggs were transferred to clean trays and additionally permitted to cool at 22-25^{0}C for 2 h before egg quality measurements. Cooled shell eggs were gently dry- wiped with clean paper tissue. Shell eggs were carefully broken, contents were divided and egg shells and yolks were discarded. Albumen of individual eggs was recovered and placed on dishes.

2.1-Turbidity measurement:

Aliquots (1 ml), containing thick and thin albumen, were transferred to cuvets. Turbidity was measured at 600 nm in spectrophotometer .Measurements were performed in duplicate using distilled water as a reference **(Shimada and Matsushita, 1980)**.

2.2-Determination of whip time, whip volumes and pH:

The functionality of blended, and non centrifuged albumen was estimated by determining whip time (min) and whip volumes (ml) as described by **Ball and Winn (1982).** The pH of non centrifuged albumin samples was determined using pH meter (Fisher Scientific, USA).

RESULTS

Table 1: Thermal inactivation of *Salmonella enteritidis* in shell eggs subjected to immersion heating in a water bath at 57^0C (n=3).

Time (min)	Survivors (log10 cfu/g)	Log10 reduction	*Salmonella* positive by enrichment testing
0	7	-	3/3
5	7	0	3/3
10	6.8	0.2	3/3
15	6.3	0.7	3/3
30	2.3	4.7	3/3
45	2.2	4.8	3/3
50	2	5	2/3
55	2	5	2/3
60	1.8	5.2	1/3
65	<1	> 6	1/3
70	0	7	0/3

Survivors (log10 cfu/g): **represent the mean of microbial counts in experiments with duplicate series repeats**.

Table 2: Thermal inactivation of *Salmonella enteritidis* in shell eggs subjected to immersion heating in a water bath at 58^0C (n=3).

Time (min)	Survivors (log10 cfu/g)	Log10 reduction	Salmonella positive by enrichment testing
0	7	-	3/3
5	7	0	3/3
10	6.7	0.3	3/3
15	3.8	3.2	3/3
30	2	5	3/3
45	1.7	5.3	3/3
50	1	6	2/3
55	0	7	0/3

Survivors (log10 cfu/g): **represent the mean of microbial counts in experiments with duplicate series repeats**.

Table 3: Thermal inactivation of *Salmonella enteritidis* in shell eggs subjected to immersion heating in a water bath at 59^0C (n=3).

Time (min)	Survivors (log10 cfu/g)	Log10 reduction	Salmonella positive by enrichment testing
0	7	-	3/3
5	6.5	0.5	3/3
10	5.5	1.5	3/3
15	3.0	4	2/3
30	1.6	5.4	1/3
45	<1	> 6	0/3
50	0	7	0/3

Survivors (log_{10} cfu/g): **represent the mean of microbial counts in experiments with duplicate series repeats**.

Table 4: Albumen quality of eggs subjected to thermal heat treatment (n= 10 eggs) in water bath at 57, 58, and 59^{0}C up to complete inactivation of *Salmonella enteritidis.*

Bath temperature (^{0}C)	Time (min)	Albumen		Whip	
		Turbidity (absorbance)	pH	Time (min)	Volume (ml)
57	75	0.07±.0.02	9.0± 0.1	10.40± 0.6*	334± 54*
58	65	0.37± 2.0*	9.1± 0.1	15.2± 6.3*	312± 60*
59	50	0.42± 2.5*	9.1± 0.1	16.2± 4.5*	299± 62*
Control	0	0.03±0.02	9.1 ±0.5	7.5±0.5	450±34

Reading represents the mean of experiments performed in duplicate per condition.

***: Significant correlation at P < 0.05, relative to control.**

DISCUSSION

1- Effects of immersion heat treatment on viability of *Salmonella enteritidis* in table eggs:

Thermal treatments were performed at 57-59^{o}C, a range of temperature previously reported for inactivation of *Salmonella* in eggs by **Lith *et al.*(1995) and Schuman *et al.*(1997)**. Treatment of inoculated eggs at 57, 58, and 59^{0}C resulted in gradual reduction of *Salmonella enteritidis* (Tables 1, 2 and 3). Inactivation in survivor occurred during the first 10 min of treatment at 57 and 58^{0}C, and during first 5 min of heating at 59^{0}C. Since treating *Salmonella* at > 50^{0}C usually inactivates the pathogen, observed microbial reduction is most likely caused by heat transfer during the early phase of immersion treatments **(Stadelman *et***

***al.*, 1996)**. Further heating of eggs produced gradual increase in internal egg temperature. Reduction of *Salmonella enteritidis* by 4.7, 5, and 5.4 log cycles was observed after 30 min heating at 57, 58, and 59^0C, respectively. The present results were compatible to that recorded by **Luis (2004)**. In this respect, **Stadelman *et al.* (1996)** reported that internal egg temperature after heating shell eggs at 57^0C for 20 and 25 min was 56.1 and 56.5^0C, respectively. These temperatures are close to the critical internal 55-56^0C, in which maximum microbial inactivation occurs. However, **Lith *et al.* (1995)** heated shell eggs, containing *Salmonella enteritidis* inside the yolk, in water at 57^0C for 20-30 min and illustrated that these treatments were not sufficient to inactivate the microorganism.

Heat treatment time/temperature conditions, aims to achieve a decrease $\leq$ 5 log10 in the number of viable *Salmonella enteritidis*, organisms. This renders the microorganisms ineffective in causing disease inactivation processes **(Stadelman *et al.*, 1996 and Schuman *et al.*, 1997)**. Reductions of *Salmonella enteritidis* by 5 log10 and 6 log10 were recorded after 50 min heating at 57 and 58 °C, respectively. Likewise**, Schuman *et al.* (1997)** heated shell eggs, inoculated in the yolk with 10^7 *Salmonella enteritidis* / g in water at 57 and 58 °C and reported microbial reductions by 5.6 log10 after 55 min and 5.8 log10 after 43 min, respectively.

Water –bath heat treatments which completely eliminated Salmonella *enteritidis* inoculum were identified. The present study revealed that immersion heating at 57^0C for 70 min was effective in eliminating all detectable *Salmonella enteritidis* by both plating and enrichment procedures .However, *Salmonella enteritidis* was completely eliminated within 55 min at a bath temperature of 58^0C and within 45 min at a bath temperature of 59^0C. In- egg shell pasteurization procedures

have been developed on the assumption that *Salmonella enteritidis* naturally resides inside the yolk, and extensive heat treatments must target the whole egg in order to transfer appropriate thermal energy to the center of the product to effectively inactivate the microorganism **(Stadelman *et al.*, 1996; Schuman *et al.*, 1997 and Brackett *et al.*, 2001)**. However, an increase in the processing temperature should not be recommended .Even if no damage to egg should occur, one may question the necessity for a margin of safety of this magnitude (10^7 kill), since such high Salmonella counts have never been encountered in egg **(Humphrey, 1999)** .Previous investigations have reported delayed inactivation of *Salmonella enteritidis* inside shell eggs during immersion heat treatments **(Hou *et al.*, 1996 and Schuman *et al.*, 1997).** Furthermore, persistence of *Salmonella* in egg after prolonged heating could be explained by clumping, protective effect of dead cells, microbial debris produced after cell destruction, and localized sites with low water activity among many other conditions **(Pflug *et al.*, 2001)**. In this respect, **Schuman *et al.* (1997)** found complete inactivation of *Salmonella enteritidis* inside shell eggs during immersion heat treatments within 50-57.5 min at a bath temperature of 58^0C and within 65 -75 min at 57^0C.

2-Albumen quality evaluation:

Of all egg components, the egg white is most sensitive to heat; egg albumen should be used as the indicator for egg quality assessment after processing **(Elliott and Hobbs, 1980)**. In general albumen quality, including turbidity and functionality was evaluated.

2.1-Albumen turbidity:

Albumen turbidity was determined from changes in its absorbance after heating eggs at three temperatures up to complete elimination of *Salmonella*. Turbidity is a direct measure of the extent of protein coagulation, as coagulated proteins are opaque and reduce the

transmittance of light through the egg white. The amount of light absorbed (absorbance) is a function of the turbidity of a liquid **(Iesel *et al.*, 2006).** Prolonged heating at 57^0C for 70 min resulted in microbial inactivation without significant affecting albumen turbidity (0.07) with respect to that measured in untreated control (0.03) (Table 4). Turbidity in eggs heated at 57^0C was lower than that of eggs heated at the other temperatures, indicated that the water bath heated shell egg at 57^0C had better transmittance than the water bath heated eggs at other temperatures. Significant ($p < 0.05$) increase in albumen absorbance by 0.34, and 0.39 was observed after 55, 45 min treatments at 58, and 59^0C, respectively. The obtained findings in this work were correlated with those recorded by **Luis (2004)**. This increase in albumen turbidity was minimal when compared to that previously reported for effective immersion heat treatments, in which heating shell eggs at 57°C for 75 min or at 58^0C for 65 min increased albumen absorbance by 0.7 and 1.3, respectively **(Schuman *et al.*, 1997).** In this concern, **Hou *et al.* (1996)** revealed that although heat treatment alone at ambient 57^0C for 25 min resulted in 5.2 log microbial reductions, it seems unlikely that prolonged heating at this temperature could achieve higher inactivation without affecting albumen clarity, reducing lysozyme activity, or affecting egg functionality.

2.2 - Whip time and whip volumes:

The turbidity detected in the albumen has been shown to have some negative effects on egg whip ability. The immersion heat treatment at 57^0C had a less effect on whip volume and yield more consistence whip times relative to heating at 58 and 59^0C. No change in albumen pH was observed in treated eggs with respect to untreated control (Table 4). Eggs are popular for the exceptional functional

properties. Egg white is used as a foaming, emulsifying, gelling and/or binding agent in numerous food preparations. Extended whip time would require for meringue preparation using immersion heated egg white. Similar observations have been recorded by **Schuman *et al.* (1997)**.

Salmonella is easy to destroy in cooking. The problem is that we often eat eggs raw or only lightly cooked. Such foods, along with eggs, should be treated as though they were contaminated. Evidence from the current study confirms immersion-heated eggs could provide Salmonella-free ingredients for the preparation of a variety of minimally-cooked foods of interest to consumers and food service operators produce eggs with acceptable quality. The trick is to reach the minimum safe internal temperature without cooking the egg, leaving a finished product that looks, acts, and tastes like a raw egg, but without the associated risk.

In order to remove or reduce the risk of *Salmonella enteritidis* food poisoning, eggs should be heat treated (pasteurized) before distribution. To block *Salmonella enteritidis* from multiplying in the egg, eggs must be held at cool temperatures (5ºC) following packing and throughout transportation. Consumers should be informed that eating undercooked eggs may result in Salmonella infection. In addition, eggs should be refrigerated to prevent proliferation of Salmonella if present and should be cooked thoroughly to kill Salmonella. Because most serious illnesses and deaths associated with salmonellosis occur among the elderly and immuno - compromised persons, these persons in particular should not eat foods containing raw or undercooked eggs. Hospitals, nursing homes, and commercial kitchens should use pasteurized eggs for all recipes requiring raw or undercooked eggs and should refrigerate all eggs and egg products. Also, wash hands, utensils, equipment, and work areas with hot soapy water before and after they come in contact with eggs and egg-containing foods. Finally, pasteurization process can be used as an

insurance system or safety net if an outbreak of this disease becomes a reality.

REFERENCES

Ball, H. R. and Winn, S. E. (1982): Acylation of egg white proteins with acetic anhydride and succinic anhydride. Poultry Science, 61: 1041- 1046.

Bell, C., and Kyrikiades, A. (2002): *Salmonella*. Blackwell Science Ltd., London.

Bennasar, A.; De Luna, G.; Cabrera, B. and Lalucat, J. (2000): Rapid identification of *Salmonella typhimurium*, *S. enteritidis* and *S. virchow* isolates by Polymerase Chain Reaction based fingerprinting methods. Internat'l Microbiol., 3: 31-38.

Brackett, R.E.; Schuman, J.D.; Ball, H.R. and Scouten, A.J. (2001): Thermal inactivation kinetics of Salmonella spp. within intact egg heated using humidity controlled air. J. Food Prot., 64(7): 934-938.

Chantarapanont, W.; Slutsker, L.; Tauxe, R.V. and Beauchat, L.R. (2000): Factors influencing inactivation of *Salmonella enteritidis* in hard-cooked eggs. J. Food Prot., 63: 36-43.

D'Aoust, J. Y. (1989): *Salmonella*. In: M.P. Doyle (ed.), Foodborne bacterial pathogens, Marcel Dekker, New York, p.327-445.

D'Aoust, J. Y. (2001): *Salmonella*. In: R.G. Labbé, and S. Garcia (ed.), Guide to Foodborne Pathogens, Wiley-Interscience, New York, p.163-191.

Elliott, R. P. and Hobbs, B. C. (1980): Eggs and egg products. In: Microbiol. Ecology of Food, Vol. II, Food Commodities. International Commission on Microbiological Specifications for Foods. PP. 521- 566. New York: Academic Press.

FDA 'Food and Drug Administration'(1998): Bacteriological

Analytical Manual. 8th Ed. (rev. A). AOAC International, Gaithersburg, Md.

Gast, R.K. and Beard, C.W. (1992): Detection and enumeration of *Salmonella enteritidis* in fresh and stored eggs laid by experimentally infected hens. J. Food Prot., 55: 152-156.

Hammack, T.S.; Sherrod, P.S.; Bruce, V.R.; June, G.A.; Satchell, F.B. and Andrews, W.H. (1993): Growth of *Salmonella enteritidis* in grade A eggs during prolonged storage. Poult. Sci., 72:373-377.

Hou, H.; Singh, R. K.; Muriana, P.M. and Stadelman, W.J. (1996): Pasteurization of intact shell eggs. Food Microbiol., 13: 93-101.

Humphrey, T.J. (1999): Contamination of eggs and poultry meat with *Salmonella enterica* serovar enteritidis. In A.M. Saeed, R.K.Gast, M.E. Potter, and P.G. Wall (ed.), *Salmonella enterica* serovar enteritidis in humans and animals: Epidemiology, pathogenesis, and control, Iowa State University Press, Ames, IA, p. 183-192.

Iesel, V .P.; Ann, V. L. and Marc, E. H. (2006): Effect of heat-treatment on the physico-chemical properties of egg white proteins: A kinetic study. J . Food Engineering, 75 (3):316-326.

Lith, L.A.; Van, J.T.; Putirulan, F.F. and Mulder, R.W. (1995): Pasteurization of table eggs to eliminate *Salmonellae*. Arch. Geflügelk., 59: 157-160.

Luis, M.S. (2004): Control of *Salmonella enterica* serovar *enteritidis* in shell eggs by ozone, ultraviolet radiation, and heat. Ph.D. Thesis. Food Science and Nutrition in the Graduate School of the Ohio State University.

McDonnell, L.R.; Feeney, R.E.; Hanson, H.L. and Sugihara, T.F. (1955): The functional properties of the egg white proteins. Food Technology, 9:49-53.

Mermelstein, N.H. (2001): Pasteurization of Shell Eggs. Food Technology, December, 72:73 -79.

Pflug, I.J.; Holcomb, R.G. and Gomez, M.M. (2001): Principles of thermal destruction of microorganisms. In: S.S. Block (ed.), Disinfection, Sterilization, and Preservation, Lippincott Williams & Wilkins, Philadelphia, PA, p. 79-129.

Ponce, E.; Pla, R.; Sendra, E.; Guamis, B. and Mor-Mur, M. (1999): Destruction of *Salmonella enteritidis* inoculated in liquid whole egg by high hydrostatic pressure : comparative study in selective and non-selective media. Food Microbiol., 16 : 357- 365.

Poppe, C. (1999): Epidemiology of *Salmonella enterica* serovar enteritidis. In: A.M. Saeed, P.K. Gast, M.E. Potter, and P.G. Wall (ed.) *Salmonella enterica* serovar enteritidis in humans and animals. Iowa State University Press. Ames, IA. pp. 3-18.

Schroeder, C. M.; Alecia, L. N. ; Wayne, D. S.; Allan, T. H.; Frederick, J. A.; Jonathon, S. R.; Eric, D. E.; Terry, D. W.; Kristin, G. H. and David, P. G. (2005): Estimate of illnesses from *Salmonella enteritidis* in eggs, United States, 2000. Emerging Infectious Diseases, 11 (1):113-115.

Schuman, J.D.; Sheldon, B.W.; Vandepopuliere, J.M. and Ball, H.R. (1997): Immersion heat treatments for inactivation of *Salmonella enteritidis* with intact eggs. J. Appl. Microbiol., 83: 438-444.

Serrano, L.E.; Murano, E.A. ; Shenoy, K. and Olson, D.G. (1997): D values of *Salmonella enteritidis* isolates and quality attributes of shell eggs and liquid whole eggs treated with irradiation. Poult. Sci., 76: 202-205.

Shimada, K. and Matsushita, S. (1980): Thermal coagulation of egg albumin. J. Agric. Food Chem., 28: 409-412.

Shirota, K.; Katoh, H.; Murasa, T.; Ho, T. and Otsuki, K. (2001):

Monitoring of layer feed and eggs for Salmonella in eastern Japan 1993 and 1998. J. Food Prot., 64 (5): 734-737.

Stadelman, W.J. (1995): The egg industry. In: W.J. Stadelman, and O.J. Cotterill (ed.), Egg science and technology. The Haworth Press, New York, p. 1-37.

Stadelman, W.J.; Singh, R.K.; Muriana, P.M. and Hou, H. (1996): Pasteurization of eggs in the shell. Poult. Sci., 75: 1122-1125.

Strantz, A.A. and Zottola, E. A. (1989): A modified plating technique for recovery and enumeration of stressed *Salmonella typhimurium* J. Food Prot., 52: 712- 714.

Tellez, I.G.; Trejo, R.M. ; Sanchez, R.E. ; Ceniceros, R.M. ; Luna, Q.P. ; Zazua, P. A. and Hargis, B.M. (1995): Effect of gamma irradiation on commercial eggs experimentally inoculated with *Salmonella enteritidis*. Radiat. Phys. Chem., 46: 789-792.

USDA, United States Department of Agriculture (1997): Pasteurized shell eggs (pasteurized in-shell eggs). Vol. 162. No. 185: 49955-57. Fed. Regist. Washington, DC.

Watkins, B.A. (1995): The nutritive value of the egg. In: W.J. Stadelman, and O. J. Cotterill (ed.), Egg science and technology. The Haworth Press, New York, p. 177-194.

Woodward, D. L.; Khakhria, R. L. and Johnson, W. M. (1997): Human Salmonellosis associated with exotic pets. J. Clinical Microbiology, 35 (11):2786-2790.

Zeidler, G. (2001): Processing and packaging shell eggs. In: D.D. Bell, and D. Weaver Jr. (ed.), Commercial chicken meat and egg production, Kluwer Academic Publishers, Norwell, MA, p. 1129-1161.