Holt, P. S., Buhr, R. J., Cunningham, D. L., and Porter, R. E. Jr. (1994) Effect of two different molting procedures on a Salmonella enteritidis infection. Poultry Science 73, 1267-1275.

effect of molting on SE infection

Qin, Z. R., Arakawa, B., Baba, E., Fukata, T., Miyamoto, T., Sasai, K., and Withanage, G. S. K. (1995) *Eimeria tenella* infection induces recrudescence of previous *Salmonella enteritidis* infection in chickens. Poultry Science 74, 1786-1792.

White Leghorn Hy-line@ cockerel

Effect of Eimeria tenella infection on SE infection was examined. Eimeria infection induced prior SE infection

Mannitol lysine crystal violet brilliant green agar

Hajna tetrathionate broth

Henzler, D. J., and Opitz, H. M. (1992) The role of mice in the epizootiology of Salmonella enteritidis infection on chicken layer farms. Avian Diseases, 36, 625-631.

SE isolation from environment

phage type of isolates from mice and cage

Manning, J. G., Hargis, B. M., Hinton, Jr., Corrier, D. E., DeLoach, J. R., and Creger, C. R. (1994) Effect of selected antibiotics and anticoccidials on Salmonella enteritidis cecal colonization and organ invasion in leghorn chicks. Avian Diseases, 38, 256-261.

Leghorn was managed on floor pens

Change of Cecal colonization and organ invasion after treatment of antibiotics

Bumstead, N., and Barrow, P. (1993) Resistance to Salmonella gallinarum, S. pullorum and S. enteritidis in inbred lines of chickens. Avian Diseases, 37, 189-193.

hen strain difference of susceptibility

Khakhria,R., and Duck,D., et al.(1991) Distribution of *Salmonella enteritidis* phage types in Canada. Epidemiology and Infection.106,25-32.

human origin phage type distribution.

Guard-Petter,J., Henzler,D.J., et al. (1997) On-Fram Monitoring of Mouse-Invasive *Salmonella enterica* Serovar Enteritidis and a Model for Its Association with the Production of Contaminated Eggs. Applied and Envionmental Microbiology. Vol.63,1588-1593.

SE isolation from mouse and egg

Correlation between mouse infection and egg contamination with SE

Humphrey,T.J., Baskerville,A., et al.(1989) *Salmonella enteritidis* phage type 4 from the contents of intact eggs:a study involving naturally infected hens. Epidemiology and Infection.103,415-423.

experiment	20W old, SE was detected in eggs at 45d after infection	
Influence of age at the time of infection		

Kramer,T.T., Reinke,C.R., and James,M.(1998) Reduction of fecal shedding and egg contamination of Salmonella enteritidis by increasing the number of Hetrophil adaptations. AVIAN DISEASES.42, 585-588.

experimental	Excresion of heterophil adapted SE	not directly related to the exposure assessment

Gast,R.K. and Benson,S.T.(1995) The comparative virulence for chicks of Salmonella enteritidis phage type 4 isolates and isolates of phage types commonly found in poultry in the United States.AVIAN DISEASES.39, 567-574.

virulence to chickens	SE PT4	not directly related to the exposure assessment

Holt,P.S.(1995) Horizontal transmission of Salmonella enteritidis in molted and unmolted laying chickens.AVIAN DISEASES 39, 239-249.

experimental study	molting caused SE contamination	

Thiagarajan,D.,and Saeed,A.M., et al. (1994) Mechanism of transovarian transmission of Salmonalla enteritidis in laying hens. Poultry Science 73.89-98.

Experimental SE infection	Mechanism of transovarian infection	not related to the exposure assessment

Nakamura,M., Nagamine,N., Suzuki,S., Norimatsu,M., Oishi,K., Kijima,M., Tamura,Y., and Sato,S. (1993) Long-Term shedding of Salmonella Enteritidis in chickens which received a contact exposure within 24 hrs of hatching. Journal of Veterinary Medical Science, 55, 649-653.

35 SPF chicks and 18 chicks were inoculated orally with $4x10^2$ SE	25/35 (71%) survived at 28w
7 weeks contact exposure	3 cecal droppings were negative, 4.5-8.5 log cfu SE in 7 were deteceted in the dead chicks, and 6.8 in remnant yolk.
SE was checked in the cecal droppings by isolation	

Schaar, U., Kaleta, EF., and Baumbach, B. (1997) Prevalence of Salmonella enteritidis and Salmonella typhimurium in laying hen flocks battery and on floor housing. Comparative studies using bacteriological and serological demonstration methods. Tierarztl. Prax. Ausg. G. Grosstiere Nutztiere, 5, 451-459.

laying chicken, 34 flocks		battery	on floor
battery and on floor	culture	47%	35.3%
	ELISA	64.7%	47.0

Giessen, A.W. Van de, Ament, A.J.H.A. and Notermans, S.H. (1994) Intervention strategies for Salmonella enteritidis in poultry flocks: a basic approach. International Journal of Food Microbiology. 21, 145-154.

164 laying flocks	flock to flock infection is important
egg yolk samples were tested antibodies by ELISA	Flocks were infected with SE from poultry house, infected vermin, and feed
	26/164 antibodiy was increased
	20% of laying flocks were infeted with SE

Mallinson, E. T., Joseph, S. W., Carr. L. E., and Wabeck C. J. (1997) Litter management is critical to food safety, performance. Feedstuffs, 69, 47-52.

drag swab sampling Kingston,1981 Mallinson1989 Avian Dis. 33,684-690	Water activity of litter affects infectious rate

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Distribution/Storage

(Pathways and product fractions)

Methods	Results
Baron,F., Gauter,M.,and Brule,G.(1999) Rapid growth of *Salmonella enteritidis* in egg white reconstituted from industrial egg white powder.Journal of Food Protection.Vol.62,585-591.	
Eggs between 3 and 10 days old from a local supermarket.	SE grew more rapidly in egg white reconstituted from powder than in raw liquid egg white.
Egg white prepared in the laboratory, or reconstituted from egg white powder produced in four factories.	SE grew more rapidly in egg white from powder pasteurized for longer period (7 or 15 days at 75°C). The SE growth in reconstituted egg white was due to egg white protein denaturation, especially ovotransferrin denaturation during powder pasteurization. Pasteurization of egg white is effective for decreasing endogeneous flora, but may be dangerous in view of postcontamination.
Curtis,P.A., Anderson,K.E.,et al.(1994) Cryogenic gas for rapid cooling of commercially processed shell eggs before packaging. Journal of Food Protection.Vol.58,389-394.	
Laid eggs were equilibrated to 21°C for 24 hr, candled, washed, and cooled.	Internal temperatures were declined to 11.1°C by 6 min cryogenic cooling process, and there was not significant shell damage within this period. When the cooling time exceeded 6 min there was a significant increase in the percentage of cracked eggs.
Liquid carbon dioxide was used for cooling in a freezer maintained at -60 +/- 3°C.	The internal temperatures were significantly different between cryogenically cooled eggs and traditionally cooled ones throughout the 119 hr cooling period.
To compare with noncooled group, cooling treatment for 3 min was given to the cooled group between washing and packaging.	The cryogenically cooled eggs had higher quality after 30 days of storage as indicated by the significantly higher Haugh unit scores, but had no effect on the albumen pH.
A half of eggs were inoculated by briefly dipping in TSB containing 10^5 CFU/ml of Pseudomonas fluorescens prior to washing.	After a 30-day storage period there was no treatment difference in external or internal microbial contamination in both inoculated and non-inoculated eggs.
External contamination of eggs was measured by rinsing with buffered peptone water (BPW) and plating on tryptic soy agar (TSA). Internal bacterial counts were determined by the method of Anderson et al. (Poult. Sci. 73, 1994)	

/2

Hammack,T.S., and Sherrod,P.S., et al. (1993) Research Note: Growth of Salmonella enteritidis in Grade A Eggs During prolonged strorage. Poultry Science. 72, 373−377.

Large brown and large white Grade A eggs were obtained from retail outlets in the Washington, DC area.

Egg shells were contaminated with SE by dipping them into inocula dilutions containing 1.7 x 10^4, 1.7 x 10^7, or 1.7 x 10^9 cfu/ml.The eggs were dried at room temperature for 20 min.

The disinfection procedures: 1) submersion in 0.1% mercuric chloride solution for 1 h, then submersion in 70% ethanol for 30 min, 2) submersion in 0.1% mercuric chloride solution for 1 h, and 3) submersion in 70% ethanol for 30 min.

The eggshell rinsings were obtained in Stomacher bags, received preenrichment in TSB, subcultured in selenite cystine (SC) and tetrathionate (TT) broths, streaked to Hektoen enteric, bismuth sulfite, and xylose lysine desoxycholate agar plates. Confirmed on triple sugar iron and lysine iron agar slants, and further with somatic antisera Group D1.

No SE cells were found on the eggshell surface treated with 0.1% mercuric chloride.

Stadelman, W. J., Rhorer, A. R. (1987) Egg quality: Which is best- In-line or off-line production? Egg Industry, 8-10.

Eggs were cooled from 95 to 60°F on pulp trays, solid top foam cartons, or on foam cartons with open tops.

Haugh units were compared between the eggs from in-line and simulated off-line.

The cooling rate and Haugh unis were not significantly influenced by the packaging materials.

Theere was no significant difference in Haugh unit quality of eggs over 3 weeks.

Age of the flock and storage temperatures was suggested to exert a much greater effect on the egg quallity.

/ 3

(Time and temperature distributions)

Methods	Results

Schoeni,J.L., .Glass,K.A., et al.(1995) Growth and penetration of Salmonella enteritidis,Salmonella heidelberg and Salmonella typhimurium in eggs. International Journal of Food Microbiology.24, 385-396.

S. enteritidis, S. Heidelberlg, S. typhimurium were inoculated into egg yolk or albumen at the concentration of 10^2 or 10^4 cfu/g of yolk or albumen.	All strains grew rapidly at 25°C at both cell number and both in yolk and albumen.
Eggs were incubated at 4, 10, or 25°C for up to 7 days.	Penetration by salmonellae was observed. The higher incidence at higher bacterial number, but independent to the day of storage.
Medium used: TSB, HEK, and confirmed by API 20E microdiagnostic kit and serological slide agglutination. Chicken feces were inoculated with salmonellae and were attached to eggs for egg penetration studies. 30 min pre and post inoculation.	

Curtis,P.A., Anderson,K.E.,et al.(1994) Cryogenic gas for rapid cooling of commercially processed shell eggs before packaging. Journal of Food Protection.Vol.58, 389-394.

See Pathways and product fractions

Saeed,A.M. and Koons,C.W.(1993) Growth and heat resistance of Salmonella enteritidis in refrigerated and abused eggs. Journal of Food Protection.Vol.56, 927-931.

See Preparation

Baker.,R.C. (1990) Survival of Salmonella enteritidis on and in shelled eggs,Liquid eggs,and cooked egg products. Dairy,Food and Environmental Sanitation,Vol.10, 273-275.

15 or 1500 cells of SE were inoculated into separated egg yolk or albumen, which were incubated at 37°C for 19days.	All strains of SE survived and grew in the yolk, but did not survive well in egg albumen.
50 cells of SE were inoculated into albumen through the egg shell, and the eggs were stored at 8°C for 14 days.	Some strains of SE migrated from albumen to the yolk but the percentage was quite low.
Eggs were dipped into 41°C water with 10^6 cells of SE, stored at 7°C or at room temperature for 15 days.	SE survived on egg shells longer at lower temperature.

Hammack,T.S.,and Sherrod,P.S., et al. (1993) Research Note: Growth of Salmonella enteritidis in Grade A Eggs During prolonged strorage. Poultry Science. 72, 373−377.

Large large white Grade A eggs were obtained from retail outlets in the Washington, DC area.

Each egg was inoculated with 1.4 x 10^4 cells SE in 0.04 ml.

Each egg was boiled individually for 1 min to provide reasonable assurance to detect SE grown in yolk.

Three pools, each consisting of 12 yolks, were formed, and MPN procedure was used to determine the number of SE per ml of egg yolk in each pool. The incubation and confirmation was performed as described in Pathways and product fractions.

The eggs were incubated at 26°C or at 2 to 8°C for 2, 5, and 16 days.

The yolks of inoculated eggs incubated 2 to 16 days at 26°C contained high levels of SE, and those incubated at refrigerated temperatures showed little, if any, gorwth of SE.

Humphrey, T.J., and Whitehead, A. (1993) Egg age and the growth of Salmonella enteritidis PT4 in egg contents. Epidemiology and Infection. 111, 209−219.

Eggs were obtained from a flock free from SE within 1-2 h of lay.

After certain period of storage, egg contents were broken out into plastic screw-capped containers. Albumen was inoculated with 500 cells of SE PT4 in 0.1 ml Ringer's solution, and kept at 20°C for 5 days.

A piece of plastic pipe was placed around each yolk to separate the yolk from albumen.

Growth rates of SE in eggs were more rapid in 21-day-old eggs or older than in fresher eggs.

Storage temperature fluctuations facilitated the growth of SE.

SE could not grow markedly in albumen separated from the yolk.

The age of the yolk was found to be the principal factor controlling the growth of SE.

Invasion of the intact yolks by SE is influenced by the age of the eggs before inoculation.

Braun,P., Felhaber,K. (1995) Migration of Salmonella enteritidis from the albumen into the egg yolk. International Journal of Food Microbiology. 25, 95-99.

1-day-old and >4-weeks-old eggs were used.

SE PT4 suspension was injected into the albumen in 0.2 ml buffered pepton water to be 10-200 cell/ml of albumen.

The eggs were stored at 7, 12, 20 and 30°C for up to 4 weeks.

The surface of the intact yolk was sterilized by flaming, and the yolk was streaked directly or after enrichnment in nutrient broth on brilliant green phenol red lactose saccharose agar.

SE was able to migrate from the albumen into the egg yolk during storage.

A positive correlation between increasing contamination dose, temperature, age of the eggs and the frequence of migration.

When SE was inoculated with a dose of 200 cells/ml albumen, the first positive egg yolks were already found after 14 days even stored at 7°C.

At 20 and 30°C the first cells were present in the yolk after 1 or 2 days.

Chen, J., Clarke, R.C., Griffiths, M. W. (1996) Use of luminescent strains of Salmonella enteritidis to monitor contamination and survival in eggs. Journal of Food Protection. 59, 915-921.

Penetration of SE studied by using bioluminescent SE GCDE and by Scnanning electron microscopy.

Eggs were immersed in bacterial solution at the concentration of 10^9 CFU/ml, and incubated at 40° C for 16 h or at 21°C for 3 days.

Eggs were infected with SE GCDE through the eggshell, some of the eggs were broken after 18 h at 37°C and thereafter kept at 4°C, others were kept at 4°C as whole eggs.

The rate of penetration increased with increasing inoculum size.

SE did not grow but survived in both shell and liquid whole eggs during refrigeration.

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

Laying hens were orally inoculated with 10^9 cells of SE PT13a and housed in single-bird laying cages.

Laid eggs were held for 7 days at 7.2 or 25°C before sampling.

3% of the freshly laid eggs, 4% of refrigerated eggs, and 16% of the eggs held at 25°C were positive for SE.

The number of SE was larger in the eggs held at 25°C, although most contaminated eggs had less than 10 or 100 cells/ml.

(Microbial growth dynamics)

Methods	Results

Zwietering,M.H., deWit,J.C., Cuppers,H.G., and van't Riet, K.(1994) Modeling of bacterial growth with shifts in temperature. Applied Environmental Microbiology. 60, 204-213.

The suitability and usefulness of several models to describe the growth of Lactobacillus plantarum with shifts in temperature was evaluated.	A temperature shift resulted in an additional lag phase.

Bradshaw, J. G., Shah, D. B., Forney, E., and Madden, J. M. (1990) Growth of Salmonella enteritidis in yolk of shell eggs from normal and seropositive hens. Journal of Food Protection. 53, 1033-1036.

10 SE in 0.1 ml were injected into the yolk of eggs from normal and seropositive hens, and the eggs were stored at 7, 15.5, and 37°C.	A generation time was 25 min at 37°C, and 3.5 h at 15.5°C in normal yolk.
Separated egg white was inoculated with 4x10^3 CFU/g and incubated at 37°C.	A generation time was 35 min at 37°C in egg yolk from seropositive hens.
The number of bacteria was counted on XLD agar.	No growth of SE was observed in liquid egg white.

Processing (Liquid Eggs)

Methods	Results

Jeantet, R., Baron, F., Nau, F., et al. (1999) High intensity pulsed electric fields applied to egg white: Effects on Salmonella enteritidis inactivation and protein denaturarion. Journal of Food Protection. 62, 1381-1386.

SE cells were inoculated to diaultrafiltered egg white at pH 7.0, 8.0, and 9.0. Inocula: 10(3), 10(5), and 10(7) cells/ml. Pulsed electric field (PEF) treatment: 0-6000Hz, up to 35kV/cm for 300 ohm*cm Counts: Tryptic soy agar, 37C, 24-28 hr	For SE inactivation, the electric field intensity was the dominant factor. The intensity had a positive interaction with pulse number. PEF treatment caused a 3.5 log SE reduction.

Schuman,J.D., and Sheldon,B.W.(1997) Thermal resistance of Salmonella spp. And Listeria monocytogenes in Liquid egg yolk and egg white. Journal of Food Protection.Vol.60,634-638.

5 strains of Salmonella including 3 SE strains were pooled and inoculated to liquid egg preparations.

5 shell eggs were used for one trial, and eggs were broken in the laboratory.

The pH was adjusted to i) 6.3 +/- 0.1 for liquid egg yolk, ii) 8.2 +/- 0.1 for liquid egg white, and iii) 9.1 +/- 0.1 for liquid egg white.

Glass capilary tubes (0.8 to 1.1 mm i.d. by 90 mm long) were used to contain inoculated liquid egg in heating procedures.

Temperature tested was 60, 61.1, and 62.2° C for egg yolk, and 55.1, 56.7, and 58.3°C for egg white.

The colonies were enumerated on BHI agar plates.

Egg yolk (pH 6.3)

Temp.	60	61.1	62.2
D-value	0.28	0.16	0.087 (min)

Egg white

Temp.	55.1	56.7	58.3
(pH 8.2)	7.99	2.96	1
(pH 9.1)	3.17	1.58	0.52

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Palumbo,M.S., Beers,S.M.,et al. (1996) Thermal resistance of Listeria monocytogens and Salmonella spp.in Liquid Egg White. Journal of Food Protection.Vol.59,1182-1186

6 strains of Salmonella including 4 SE strains were mixed for the experiments.

Commercially broken raw egg white was obtained from local egg processors.

Large number of bacteria (8.5 to 9.0 CFU/g) was inoculated to allow use of nonselective media for enumeration without interference by the natural background flora.

Samples were heated in glass vials (15 mm e.d. by 60 mm high),which were submerged in a water bath, at 51.5 and 53.2°C with H2O2, at 55.5, 56.6, and 57.7°C without H2O2.

The survived bacteria were enumerated by plating on TSA.

Temp.	51.5	53.2	55.5	56.6	57.7
H2O2	yes	yes	no	no	no
D-value (min)	3.87	1.6	2.74	1.44	0.78

Z-value for no-H2O2 Salmonella spp. was 4.03°C .

At 56.6°C ,

pH		7.8	8.2	8.8	9.3
D-value	3.6	2.14	1.59	1.08	

Palumbo,M.S., Beers,S.M.,et al.(1995) Thermal resistance of Salmonella spp. And Listeria monocytogenes in Liquid egg yolk and Egg yolk products. Journal of Food Protection.Vol.58,960-966.

6 strains of Salmonella including 4 SE strains were examined individually for their thermal resistance. The influence of aw-lowering ingredients such as salt and sugar was investigated using a mixture of 6 strains.

Commercially broken raw egg yolk was obtained from local egg processors.

Large number of bacteria (8.5 to 9.0 CFU/g) was inoculated to allow use of nonselective media for enumeration without interference by the natural background flora.

Samples were heated in glass vials (15 mm e.d. by 60 mm high),which were submerged in a water bath, or received actual plate pasteurization procedures.

for SE

Temp.	60	61.1	62.2
D-value	0.55-0.75	0.27-0.35	0.21-0.30

z-value: 4.61-6.55°C

With aw-lowering ingredients, D-value increased at the range of 61.1 - 66.7°C .

Log reduction of SE in 3.5 min of current pasteurization standards decreased in the presence of salt and/or sugar.

Baker,R.C. (1990) Survival of Salmonella enteritidis on and in shelled eggs,Liquid eggs,and cooked egg products. Dairy,Food and Environmental Sanitation.Vol.10,273-275.

Thermal death time for SE strains in liquid whole egg was studied using neck flasks.	D-value at 60 ° C was 0.32-0.69

Garibaldi,J.A., Lineweaver,H., et al.(1968) Number of salmonellae in commercially broken eggs before pasteurizatoin. Salmonellae in Eggs. 1096-1101.

Samples were taken from the mixing tank at commercial plants immediately after break out.

by MPN method consisting of pre-enrichment in lactose broth (LB), enrichment in Selenite-Cystine broth, and plating on Brilliant Green (BG) agar.

Suspected colonies were confirmed by Triple Sugar Iron (TSI) method, then were serologically checked.

Percent of Salmonella positive sample was 6.7 in winter-spring season, and 54 in summer-fall.

Level of salmonellae (not only SE)

MPN	<1	1.4-2.9	5.3	24	110
No. of 86 samples	10	1	2	1	

Samples with low standard plate count tends to give fewer salmonella positives.

No correlation was proved between the grade of eggs and number of salmonella positives.

International Association of Milk, Food and Environmental Sanitarians (1976) E-3-A Sanitary standards for liquid egg products cooling and holding tanks. No. E-1300. J. Milk Food Technol. 39, 568-575.

Sanitary Standards for liquid egg products cooling and holding tanks

CONTENTS

Scope, definitions, materials, fabrication, cooling, and appendix.

STANDARDS

Whites not to be stabilized

to be held <= 8 hr : <= 55F

to be held > 8 hr : <= 45F

within 2 hr after pasteurization : <= 45F

Whites to be stabilized

to be held <= 8 hr : <= 70F

to be held > 8 hr : <= 55F

within 2 hr after pasteurization : <= 55F

Liquid egg product with 10% or more salt added

if to be held <= 30 hr : <= 65F

ir to be held > 30 hr : <= 45F

All other product

to be held <= 8 hr : <= 45F

to be held > 8 hr : <= 40F

within 2 hr after pasteurization : <= 45F or 40F depending on holding time

within 3 hr after stabilization : <= 45F or 40F depending on holding time

Chen,J., Clarke, R. C., and Griffiths, M. W. (1996) Use of luminescent strains of Salmonella enteritidis to monitor contamination and survival in eggs. Journal of Food Protection 59, 915-921.

See Distribution, Storage (Time and temperature distribution)

2/

Preparation
(Cooking models)
(Time and temperature distributions)

Methods	Results
Saeed, A.M., and Koons, C.W.,(1993) Growth and heat resistance of Salmonella enteritidis in refrigerated and abused eggs. Journal of Food Protection.Vol.56, 927-931.	
Fresh nest-run eggs were obtained from a SE-free flock.	At 23°C, SE grew to 10^9 CFU/ml eggs within 72 hr. Little growth of SE was observed in refrigerated eggs.
250 eggs were inoculated into the yolk with 20 CFU of SE PT8 in 50μl sterile saline.	Time distribution (s): Frying (50-175), Scrambling (50-170), Omelet (60-205), Boiling (180-2700)
Half of eggs were stored at 23°C (storage abuse) and the others were stored at 4°C in a refrigerator.	Temperature distribution (°C): Frying (45-85), Scrambling (67-85), Omelet (72-92), Boiling (62-92)
Every other day, two eggs were tested for viable SE plate count on XLT4 agar, and eight eggs were cooked in four ways (two per method): frying, scrambling, omelet, and boiling in fume food.	SE was detected after cooking at higher rates in eggs stored at room temperature, especially those stored for longer than 5 days.
Baker, R.C., (1990) Survival of Salmonella enteritidis on and in shelled eggs,Liquid eggs,and cooked egg products. Dairy,Food and Environmental Sanitation,Vol.10, 273-275.	
The time required to destroy SE by cooking methods was determined. The methods included scrambling, poaching, boiling, and frying.	The final temperatures of each method of cooking (°C): Scrambling (74), Poaching (75), Boiling (75), Frying-covered (70), -sunnyside (64), -turned over (61).
1x10^8 SE were injected into the yolks, the inoculated eggs were stored at 12°C for 24 hr, and cooked. Samples were taken every 15 seconds.	Time needed for complete kill (min): Scrambling (1), Poaching (5), Boiling (7), Frying-covered (4), -sunnyside (7), -turned over (3+2).
Hou, H., Singh, R.K., et al. (1996) Pasteurization of intact shell eggs. Food Microbiology,13.93-101.	
Microbial growth dynamics	
Time and temperature distribution	
Water-bath and hot air ovens were used for pasteurization of intact shell eggs using the two heating methods and these combination.	In a 57°C circulating wter-bath for 25 min gave reductions in S. enteritidis ATCC 13076 of about 3 log cycles.
Lysozyme activity was measured by change of OD450 of Micrococcus lysodeikticus	In a 55°C hot air oven for 180 min gave a 5 log reduction.
The viscosity of the egg white was measured with viscometer.	A combination of two methods (water-bath heating at 57°C for 25 min followed by hot-air heating at 55°C for 60 min) produced 7 log reductions.
The turbidity of the egg white was measured with spectrophotometer at 600 nm.	Lysozyme activity and physical properties (turbidity and viscousity and so on) of egg white indicated overall functional at 57°C for 25 min in water-bath.

Evans, M.R., Parry, S.M., et al.(1995) Salmonella outbreak from microwave cooked food. Epidemiology and Infection. 115,227－230.

Cooking models
Mixing and use of eggs

Making a list of foods served at the buffet with details of the preparation

A structured questionnaire of personal details, clinical details of illness and food consumption histories
The microbiological analysis of faecal specimens and samples of leftover foor or food ingredient

6 of 7persons reported illness with diarrhoea, abdominal pain, fever and headache.

All had become ill the day following consumption of the buffetmeal. (a median incubation period is 17.5h)
Faecal samples of 4 persons show positive for Salmonella enteridis PT4.

Salmonella enteridis PT4 with 6x10^3 /gm cells was isolated from leftover samples of a savoury rice dish (contained boiled rice, raw carrot, eggs, cheese and curry powder)

The curry powder and remainder of the packe of six eggs were negative on microbiological analysis.

The savoury rice dish had been prepared by heating in a 500W microwave oven with rotating turntable on full power for 5min.

Bradford, Humphrey, T.J.,et al.(1997) The cross－contamination and survival of Salmonella enteritidis PT4 on sterile and non－sterile foodstuffs. Applied microbiology. 24, 261－264.

Cooking models
Mixing and use of eggs
Microbial growth dynamics

Formica square (2 cm^2) were contaminated with the PT4 (Contamination levels were 10^5-10^4 cells per square) isolates suspended in homogenized whole eggs.
Sterile melon or beef pieces were placed onto the contaminated egg droplets and removed after 1, 5, 10, 30 s or 1, 3, 5, 10, 30 min.

The food pieces were examined for the presence of salmonella by enriched culture folowed by plateing on XLD at 37℃ for 18-24h.

Salmonella-like colonies were identified using standard serological techniques.

When the foods were placed on these surfaces where egg droplets were still wet, cross-contamination occurred within 1s onto piece of food.

At least 1 min for all the food pieces to be contaminated when egg droplets had been allowed dry.

Both strain of isolate E and isolate I were capable of rapid growth on melon and beef.

The growth rates on beef was slowed by pre-exposure to either 4 or -18℃.

Evans,M.R., Hutchings,P.G., et al.(1996) A hospital outbreak of salmonella food poisoning due to inadequate deep—fat frying. Epidemiology and Infection. 116, 155—160.

Pathways descriptions
Cooking models

Methods

Epidemiological investigation:	A questionnare and Data analysis using Epi Info.
Microbiological Investigation:	Sampling faecal specimens from all residents and ill staff, and Serotyping, and phage typing and plasmid analysis
	Sampling from ingredient used for the implicated foodstuff (including eggs and bread crumbs) Eggs were cultured for salmonellae selected media, and other food were enrichment in single strength selenite broth.
Environmental investigation	Kitchen facilities inspection, interview of staffs

Results
At a hospital for mentally handicapped people in July 1990, 101 residents and 8 staffs were affected by outbreak of Salmonella enteridis PT4 food poisoning.
A cohort study implicated beef rissoles cooked by deep-fat frying as the vehicle of infection.
Replication of the cooking process demonstrated that the rissoles achived core tempreture of 48-60℃ despite external temprature was 91-95℃ and oil temprature was 142-154℃.
Salmonella enteridis PT4 was isolated in shell eggs from the hospital kitchen.

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Xiong, R., Xie, G., and Edmondson, A. S. (1999) The fate of Salmonella enteritidis PT4 in home-made mayonnaise prepared with citric acid. Letters in Applied Microbiology 28, 36-40.

SE (PT4) was inoculated at 10(6)/g into home-made mayonnaise prepared with citric acid .

Ratios of egg yolk to citric acid were 0.57-2.0.

Samples were stored at 5 and 22C and taken at intervals.
XLD agar plate for counts, 37C, 24hr

The organism did not grow in all samples with pH <4.05.

The smaller the ratio, the shorter the survival time period of SE.

The inactivation at 22C was more rapid than at 5C.

TO ACHIEVE SE FREE MAYONAISE PREPARED WITH CITRIC ACID, pH SHOULD BE <3.3.

Klontz, K. C., Timbo, B., Fein, S., and Levy, A. (1995) Prevalance of selected food consumption and preparation behaviors associated with increased risks of food-borne disease. Journal of Food Protection. 58, 927-930.

A national telephone survey in 1992-1993 was done. A total of 1,620surveys were completed, representing a response rate of 65%.

The percentages of survey respondents who reported consuming:

raw eggs	53
undercooked humbergers	23
raw clams or osters	17
raw sushi or ceviche	8

A fourth of the respondents said that after cutting raw meat or chicken, they use the cutting board again without cleaning it.

Safer food consumption and preparation behaviors were consistently reported by females at least 40years old with a high school education or less.

Anellis, A., Lubas, J., and Rayman, M. M. (1954) Heat resistance in liquid eggs of some strains of the genus Salmonella. Food Research, 19, 377-395.

The heat resistance in liquid whole egg of ten Sal. strains was studied.
Cells incubated in tryptose broth were washed.
TDT tube (10x75 mm), 1.1 ml/tube, 10(5) cell/ml
Submerged in a glycerol bath.
TheTDT tubes were incubated at 37C for 5 days and survivors in them were detected by incubation in tryptose broth at 37C for 48 hr.
D values were estimated from L.D.50.

Strain	140F, pH5.5 D (min)	z (F)
S. pullorum	0.4	7.5
S. worthington	1.1	7.7
S. oranienburg	1.3	8.1
S. montevideo	1.4	8.2
S. meleagridis	1.6	7.8
S. typhimurium	2.2	7.8
S. senftenberg	9.5	10.2

Garibaldi, J. A., Straka, R. P., and Ijichi, K. (1969) Heat resistance of Salmonella in various egg products. Applied Microbiology, 17, 491-496.

The heat resistance chracterisitcs of Sal. typhimurium		D (min) at 60C	Z value (C)
Tm-1 were determined in various egg products.	whole egg, pH9.2	0.27	4.3
Egg products inoculated with the cells at the final	whole egg plus 10%sucrose	0.6	4.6
conc.of 10(7)/ml were heated in sealed ampoules	fortified whole egg	1	5.3
completely submerged.	egg white, pH 7.3 stabilized with alminum	0.2	4.2
Count: tryptocase soy plus 2% yeast extract-agar	egg yolk	0.4	4.4
plates, 35C, 24 or 48 hr	egg yolk plus 10%sucrose	4	4.8
	egg yolk plus 10%NaCl	5.1	4.6
	scrambled egg mix	1	5.3
		D (min) at 55C	average Z
	egg white, pH 9.2	0.55	4.6
	egg white, pH 9.2 plus 10%sucrose	1.2	

Shah, D. B., Bradshaw, J. G., and Peeler, J. T. (1991) Thermal resistance of egg-associated epidemic strains of Salmonella enteritidis. Journal of Food Science 56, 391-393.

Test cultures of SE were prepared by incubation in		D values for SE C398 (sec)	
trypticase soy broth supplemented with 0.6% yeast	temp (C)	liquid whole egg	TSBYE
extract (TSBYE). The test cultures were inoculated	54.4	1131.8	599
into liquid whole egg, yolk, or TSBYE at 2x10(6)	57.2	154.6	120.2
CFU/ml. Aliquots (2ml) in sealed glass tubes were	60	21.8	23.4
submerged in a water bath at constant temps.	62.8	3.8	3.2
Counts: trypticase soy agar, 25C, 7days	Z value (C)	3.3	3.7

Muriana, P. M. (1997) Effect of pH and hydrogen peroxide on heat inactivation of Salmonella and Listeria in egg white. Food Microbiology, 14, 11-19.

SE ATCC13076 was incubated in tryptic soy broth containing yeast extract at 35C for 12-14 hr. Liquid egg wite inoculated with SE cells were heated in a flow-injection bench-top pasteurizer system at 56.7C for 4.1 min. Counts: tryptic soy agar	The heating provied greater than a 7.5-8.5 log decrease in SE at pHs 8.32, 8.66, and 9.0.

Schuman, J. D., Sheldon, B. W., et al. (1997) Immersion heat treatments for inactivation of Salmonella enteritidis with intact eggs. Journal of Applied Microbiology 83,438-444.

Each six SE isolate was incubated in tryptic soy		58C	57C
broth at 37C for 24h.	complete inactivation period (min)	50-57.5	65-75
Pooled SEcells were inoculated into intact shell eggs	come-up time (min)	24-35	24-35
(3x10(8) CFU per egg). The eggs were immersed in a water bath at 58 and 57C.	apparent D value (min)	4.5	6
Count: triptic soy agar overlaid with xylose lysine deoxycholate at 37C for 48h			

Schuman, J.D., Sheldon, B.W., Vandepopuliere, J.M. and Ball, H.R., Jr. 1997. Immersion heat treatments for inactivation of Salmonella enteritidis with intact eggs. Journal of Applied Microbiology,83:438-444.

Eggs were inoculated near thegeometric center of the yolk with ca 8.5 log CFU of pooled SE cells. The eggs were immersion heated in a water bath at 58 and 57C.	At 58C	SE cells were reduced by 3.9-5.0 log during the initial 35 min. Cells were completely inactivated within 50-57.5 min (a 8.4-8.5 log reduction). apparent D value 4.5 min
	At 57C	SE cells were reduced by 2.0-2.5 log during the initial 35 min. Cells were completely inactivated within 65-75 min (a 8.4-8.5 log reduction). apparent D value 6.0 min

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

SE ATCC 13076 cells suspended in egg yolk were inoculated into shell eggs. Inoculated eggs were heated in a water bath at 57C for 25 min or a hot air oven at 55C for 3 hr, or with a combination of a water-bath heating at 57C for 25 min and a hot air heating at 55C for 1 hr. 57C for the water bath and 55C for the hot air oven were maximum temperatures that could be used without denaturating the egg components. counts:TS agar, 37C 2-3 day	The water bath treatment caused a 3 log SE reduction. The hot air treatment caused a 5 log SE reduction. The combined treatment caused a 7 log SE reduction.

Imai, C., and Kurihara,T. (1992) Heat resistance of Salmonella New food industry. Vol.34,91－95. 51－56.

New Food Indutry Vol.34, No.1 (1992), 91-95, No.2,
(1992), 51-55

Time and tempreture distributions

Surveys on tempreture of strage snd handling of eggs

Surveys on cooking practices - temperatures and times applied

Cooking models

Results (Review)
Heat Resistration of salmonella in liquid eggs

Osborn et al reported that D-value at 58.9℃ was 0.28-0.62 min for 4 strains isolated from whole eggs, and 0.8-1.2 min for strains isolsted from egg yolks.

Garibaldi et.al. reported that D-values at 60℃ was 0.27 min in whole eggs, 0.60 min in whole liquid egg with 10% sugar, 5.1 min in liquid egg yolk with 10% salt, and 1.0 min in scrambled egg mix.

Cotterill et al. found that the reduction rate of S.senftenberg 775W in egg white at 55.3℃ at pH9.3 was less than that of S.enteritidis.

Galbaldi reported that in order to sterilize Salmonella in egg yolk for mayonnaise and dressing, less temprature and shorter time for heating was required with little amount of acetic acid.

The positive rate of salmonellae of non-steriled eggs in worst insanitary factory among 4 liquid egg processing factories in Japan was 84.1%, while the positive rate in steriled eggs was 0% in this factory.

Heat Resistration of salmonella entiritidis

D-value for Salmonella enteritidis was 0.4 min at 60 ℃ in whole eggs, 1.1 min at 60℃ in egg yolk and 1.5 min at 55℃ in egg white.

A few S.enteritidis cells were survived in hard-boiled eggs and scrambled egg with inocurum of 10^8 per egg yolk.

The central part of soft-boiled eggs, scrambled egg and soft fried eggs was hardly heated at more than 60 ℃.

The survival of S.enteritidis was studied in cooked food as follows;

S. enteritidis was completely killed in sponge cake.

In cooking of donuts, the duration of flying was more inportant than temperature of oil.

In cooking of thick food with much air like souffle, longer baking period was required.

Chuhei Imai and Etsuko Nakamaru, Yushi 43 (3), 63-71(1990) in Japanese

Chuhei Imai and Etsuko Nakamaru, Yushi 43 (9), 62-70(1990) in Japanese