UEP

Washington Office

One Massachusetts Avenue, N.W., Suite 800
Washington, D.C. 20001
(202) 842-2345 • Fax (202) 408-7763 • Fax (202) 682-0775

United Egg Producers

Al Pope
President

Ken Klippen
V.P. Government Relations

Michael McLeod
Washington Counsel

Randy Green
Sr. Government Relations Rep.

June 13, 2002

Mr. Joseph Levitt
Director of the Center for Food Safety
and Applied Nutrition
Food and Drug Administration
5100 Paint Branch Parkway
College Park, Maryland 20740

Dear Joe:

On behalf of United Egg Producers (UEP), a national cooperative of egg producers representing 85% of all the shell eggs produced in the U.S., and United Egg Association (UEA), a national association representing 95% nationwide of all the further processed egg products, we seek your assistance on two issues affecting the U.S. egg industry. The first involves the issuing of a temporary permit to Kraft Foods, Inc. for "salad dressing". The second issue involves FDA's recommendation to cook eggs until the yolks are firm following the egg labeling final rule.

Salad Dressing that deviates from the U.S. Standards of Identity

Background
FDA/CFSAN issued a temporary permit on April 12, 2001 (66 FR 18957) for test marketing of 150 million pounds during a 15-month period. In anticipation of Kraft Foods, Inc. filing for a permit that allows the permanent marketing of salad dressing with a reduction from 4% to 2% (50% reduction) in the quantity of egg yolk, both UEP and UEA have serious concerns with granting the permit for three reasons; (1) nutrition, (2) organoleptic, (3) economics. 21 CFR §169.150 (a) describes "salad dressing" as containing egg-yolk ingredients equivalent to 4 percent by weight of liquid egg yolks. As specified in paragraph (c) salad dressing may contain "liquid egg yolks, frozen egg yolks, dried egg yolks, liquid whole eggs, frozen whole eggs, dried whole eggs, or any one of the forgoing ingredients" along with vegetable oil(s), stabilizers, thickeners, spices and salt and potassium sorbate (a fungistatic agent for foods). Consumers may not recognize all the ingredients that make up salad dressing, but changes in the basic ingredient of egg yolks would compromise the noticeable standards for salad dressing. A 50% reduction in the egg yolk content would alter the product both organoleptically and nutritionally.

Nutrition
Egg yolks contain the fat soluble vitamins A, D, K, and E. Vitamin E is a powerful antioxidant that protects our body by neutralizing cell damage. Choline is found in egg yolk and has been shown to contribute to memory enhancement in both children and the elderly. Lutein and Zeaxanthin have been shown to protect against macular degeneration in elderly while serving as an antioxidant. Also, Lutein and Zeaxanthin, found in egg yolks are more bioavailable than other sources.

Forty percent of the protein of the egg (6.25 gm protein in a large egg) is found in the yolk. To reduce the egg content by 2% in salad dressing (a 50% reduction) would greatly diminish the nutrient content.

Furthermore, any claims in an application for a 2% reduction of eggs in salad dressing would give the consumers the wrong impression and perpetuate a myth that removing egg yolk is health advantage. Also, it contradicts current scientific evidence that there is no relationship between dietary cholesterol and heart disease risk.

Organoleptically
The sensory organ of taste would most likely detect a 50% reduction of egg yolk in the "mouth feel" of salad dressing. This is evident in the fat reduction of milk (1%, 2%, fat-free) and would most likely be perceived by consumers as a "watered down" version of salad dressing.

Economics
The egg industry is suffering from a sustained period of depressed egg prices. Since the beginning of 1999, the industry has expanded its laying flock by 17.4 million hens. The average producer price in 2001 was 14.4% below the average price for 1997-2000. Liquid whole egg reached a five year price low this year. When UEA petitioned for a bonus buy of egg products, the price reporting system of Urner Barry reflected prices that were 18% below the previous year ($.3576 in 2000 compared to $.2952). Urner Barry prices continued to fall another 1% and were 14% below year earlier levels ($.3408 in 2000 compared to $.2929). The average price for the year compared to a 5 year average was down 14% ($.3444 for a 5 year average compared to $.2985).

The USDA Agricultural Marketing Service has responded to these depressed prices in the U.S. egg industry with federal funding of two bonus buys of egg and fowl products in its federal feeding programs amounting to $20 million. It is ironic that one federal agency is allocating funding to support the depressed economic conditions of an industry while another may contemplate a program that will serve to exacerbate those conditions requiring additional federal outlays of capital.

Conclusion
UEP and UEA respectfully request that FDA/CFSAN not issue a permanent permit to any company that seeks to alter the standards of identity or nutritional characteristics for salad dressing and that egg yolk continue to constitute 4 percent by weight of salad dressing.

FDA's Recommendation to Cook Egg Yolks Until Firm

Following issuance of the egg safe handling instructions (21 CFR §101.17 (h)), CFSAN issued its Food Safety Facts for Consumers in August 1999 (copy enclosed). The recommendations from CFSAN included "**cook eggs until both yolk and the white are firm.**" The former Commission Dr. Jane Henney was quoted in the major media as advocating "no more sunny-side up eggs". The egg industry felt that FDA went beyond what was necessary to safeguard the health of consumers. Research was commissioned at North Carolina State University (copy enclosed). The study entitled *"Related Time/Temperature Data and Cooking Recommendations of Shell Eggs to the Thermal Inactivation of Salmonella Enteritidis"* clearly demonstrates that consumers can enjoy eggs safely with yolks that are beginning to thicken and heated to proper temperature..

While consumers have continued to enjoy these "runny" eggs despite FDA's recommendations, the incidence of *Salmonella* Enteritidis has trended downward. The CDC Morbidity, Mortality Weekly Report dated April 19, 2002 reported in its comparison 1996-2001 that *Salmonella decreased 15%* and *S.* Enteritidis decreased 22%. In the editorial note the decline was attributed to factors including "egg quality assurance programs for *S.* Enteritidis.

With the decline in the incidence of S. Enteritidis and the improvements in quality assurance by the nation's egg producers, UEP and UEA respectfully requests that FDA amend its recommendations on egg cooking to allow for consumers to enjoy eggs safely with yolks beginning to thicken and heated to proper temperature.

Thank you for considering these requests.

Yours sincerely,

Elliot Gibber	Mike Bynum	Al Pope	Ken Klippen
UEA Chairman	UEP Chairman	President	Vice President

FDA CFSAN

FOOD SAFETY FACTS FOR CONSUMERS

Center for Food Safety and Applied Nutrition, U.S. Food and Drug Administration

August 1999

Playing It Safe With Eggs

Fresh eggs may contain bacteria that can cause an intestinal infection called salmonellosis. Most healthy people recover from these infections within 4-7 days but they can lead to severe and even fatal illness, especially for those most vulnerable to foodborne disease—children, the elderly, and persons with immune systems weakened by health problems. You can avoid illness from eggs by knowing how to buy, store, handle and cook them—or foods that contain them—safely.

Buy Safe

- **Buy eggs only if sold from a refrigerator or refrigerated case. Open the carton and make sure that the eggs are clean and the shells are not cracked.**
- **Store eggs in their original carton and refrigerate as soon as possible.**

Keep Clean and Don't Cross-contaminate

- Wash hands, utensils, equipment, and work areas with hot, soapy water before and after they come in contact with eggs and egg-containing foods

Cook Thoroughly

- **Cook eggs until both the yolk and the white are firm. Scrambled eggs should not be runny. Casseroles and other dishes containing eggs should be cooked to 160°F (72°C)**
- If a recipe calls for eggs that are raw or undercooked when the dish is served, replace it with a recipe that contains only thoroughly cooked eggs.
- Serve cooked eggs and egg-containing foods immediately after cooking. For buffet-style serving, hot egg dishes should be kept hot, and cold egg dishes kept cold. Eggs and egg dishes, such as quiches or soufflés, may be refrigerated for serving later but should be thoroughly reheated to 165°F (74°C) before serving.

Refrigerate or Freeze for Safety's Sake

- **Refrigerate raw shell eggs immediately after purchase and use them within 4 to 5 weeks.**
- Use hard-cooked eggs (in the shell or peeled) within I week after cooking.
- Cooked eggs, including hard-boiled eggs, and egg-containing foods should not sit out for more than 2 hours. Within 2 hours either reheat or refrigerate.
- Use frozen eggs within one year. Eggs should not be frozen

Relating Time/Temperature Data and Cooking Recommendations of Shell Eggs to the Thermal Inactivation of *Salmonella* Enteriditis

Final Report
Submitted to:
American Egg Board/Egg Nutrition Center

North Carolina State University
Patricia Curtis, Ph.D.
Joanna Tharrington

Relating Time/Temperature Data and Cooking Recommendations of Shell Eggs to the Thermal Inactivation of *Salmonella* Enteriditis

Introduction:

From 1988 to 1996, *Salmonella* Enteriditis (SE) was the most common cause of all foodborne disease outbreaks in the United States, with undercooked eggs being the primary source of infection. After years of increases in reported cases, epidemiological studies suggest that SE infections are decreasing (13). While the implementation of new quality and safety programs by the nation's egg industry appears to be having positive effects, SE remains an important health concern.

There are two pathways of contamination of an egg by SE. It is possible for the egg to be infected during formation or by translocation of the organism through the shell. Investigators have demonstrated that ovarian infection is the most likely route of infection (7). Subsequent growth of the bacteria is predominantly regulated by temperature and storage time. If these infected eggs are subjected to temperature abuse, the SE can grow to high enough concentrations that some cells could survive an inadequate cooking process. The contents of an infected egg typically show no changes in appearance or odor that would alert the consumer. While there is a possibility of bacterial contamination in retail eggs, proper cooking can eliminate the risk of food borne illness from SE. Citing increased health concerns over this egg-related pathogen new labeling has been mandated. Shell eggs that have not been specifically treated to destroy all viable *Salmonella* are to be labeled with safe handling instructions as specified in 21 CFR 101.17h.

SAFE HANDLING INSTRUCTIONS: To prevent illness from bacteria: keep eggs refrigerated, cook eggs until yolks are firm, and cook foods containing eggs thoroughly.

Some recommendations on safe egg cookery include:
FDA – *cook until yolk is firm; cook all parts of the food to 63°C (145°F) for 15 seconds*

American Egg Board – *scrambled – cook until the eggs are thickened and no visible liquid remains*
fried and poached – cook slowly until the whites are completely set and the yolks begins to thicken but are not hard

USDA – *Cook eggs thoroughly until both the yolk and white are firm. Those electing not to consume hard-cooked eggs can minimize their risk by cooking the egg until the white is completely firm and the yolk begins to thicken but is not hard. Scrambled eggs should be cooked until firm throughout.*

Consumer preferences do not always agree with the recommendations of cooking eggs to complete firmness. This study was designed to investigate the time-temperature relationship of yolk and albumen consistencies to explore the possibility of cooking eggs to a specific temperature or visual endpoint that would ensure the destruction of SE while leaving the yolk less than solid. Our objective was to relate time and temperature combinations that will destroy SE to cooking procedures that would be appropriate and easy to follow.

Background:

Heat coagulation of egg components does not occur instantaneously at a given temperature. Turbidity develops and an increased viscosity of albumen is seen at 57°C (135°F). Coagulation begins at about 62°C (144°F) for albumen and 65°C (149°F) for yolk. The albumen ceases to flow at about 65°C (149°F) and the yolk at 70°C (158°F). Whole egg coagulates between 62°C (144°F) and 70°C (158°F) and toughens extensively at 80°C (176°F). Temperatures required for coagulation are elevated by dilution, as seen when liquid (water or milk) is added to eggs for scrambling (23). Research has shown that the coagulation properties are different between intact yolks and blended yolk (22).

Existing research has determined D and z_D values (temperature change (°C) necessary to effect a 10-fold change in the D-value) for SE inoculated into egg yolk, albumen and whole egg. D values for a given organism are dependent on growth media, thus values obtained in egg yolk would be different from those measured in albumen, whole egg or other food products. *Salmonella* has been found to be significantly more heat resistant in egg yolk than in either albumen or homogenized whole egg due to the differences in pH, fat and moisture content (8, 21). For this reason, we only considered the D and Z_D values determined in yolk. Schuman *et al.* (19, 20) have provided extensive kinetic data documenting the heat resistance of stationary phase *Salmonella* spp. in yolk and albumen using an immersed sealed glass capillary tube procedure. The *Salmonella* strains used included three *S.* Enteritidis and two *S.* Typhimurium. They found D-values ranged from 0.087 minutes at 62.2°C to 0.28 minutes at 60°C in yolk, and from 1.00 minute at 58.3°C to 7.99 minutes at 55.1°C in albumen (pH 8.1). Mean z_D -values for *Salmonella* ranged from 3.54 to 4.33°C. These are similar to the results of Garibaldi *et al.* (6) and Michalski *et al.* (12). The differences in reported bacterial thermal inactivation data between researchers could be attributed to many factors, including the geometry of the heating vessel used. While other investigators have reported higher D and Z_D values, the ones determined by Schuman *et al.* are used in this paper due to the documented advantages of using the capillary tube procedure (3). SE has proved to be more heat resistant than other common salmonellas with the exception of *S. senftenberg* (3, 8, 14). *S. senftenberg* has the highest known heat resistance of any of the salmonella, but was not considered in this study because it is rarely associated with eggs. Strain and growth media are not the only factors affecting heat resistance. Stationary phase cells have been shown to be more heat resistant than log (growth) phase cells (8) and the addition of salt may also affect the rate of cell destruction. Palumbo *et al.* (15) and Cotterill *et al.* (4) determined that the decrease of water activity caused by addition of solutes such as salt or sucrose decreases the rate of cell destruction with increased temperature increments. Salt was shown to protect S. *typhimurium* cells against heat inactivation in whole egg by Jung and Beuchat (10). The effectiveness of a heat treatment is dependent on initial microbial counts. It has been reported that in liquid whole egg samples that have tested positive for salmonella, counts are extremely low. A summary of studies states that 93% of the positive samples contained less than 1 salmonellae/g and none contained more than 110 salmonellae/g (5). While these initial counts may be low, temperature abuse during storage could result in much higher numbers that would challenge the effectiveness of cooking.

Materials and Methods:

Freshly laid, washed and sized shell eggs were obtained from the Piedmont Research Station, Salisbury, N.C. They were candled to detect the presence of defects and subsequently stored at 4°C prior to use. Time / temperature profiles of the consistency and visual appearance of egg yolk and albumen were examined during the application of five cooking methods: poaching, boiling (hard and soft cooked), scrambling, sunny-side-up and over-easy. Three egg sizes were used to analyze the relationship of area to heating rate and heat penetration; U.S. Grade A medium (47-54 g), large (54-61 g) and extra large (61–68 g). Individual egg weights were recorded and the rate of heat penetration during cooking was determined on six replicate eggs for each of the three sizes. Digital photographs were taken to aid in visual descriptions.

Cooking Procedures:

Time-temperature profiles for the hard and soft cooked eggs were constructed with the use of type T 32 gauge wire thermocouples attached to a digital logger. Each egg was measured with calipers to determine distance to its geometic center. The thermocouple was threaded through the egg by means of small holes punctured in each end so that the junction was located at the center of the egg. A candler was used to aid in this process. The wire was secured and the apertures sealed with epoxy resin. Temperature measurements of the eggs were recorded at 0.5-minute intervals and plotted. Figure 1 shows the thermocouple placement in the yolk of an egg after cooking.

Two cooking methods for the hard and soft cooked eggs were used. In the method described by the American Egg Board, a single layer of six eggs was placed in a 1.5-quart (1.42 liter) saucepan. Tap water (21°C ± 2°C) was added to a level approximately 2.5 cm (1 in) above the eggs. The pot was covered, brought to a boil over medium-high heat (10 minutes ± 0.5) then immediately removed from the heat source. To prepare hard cooked eggs, large sized eggs were allowed to stand covered in the hot water for 15 minutes. The time was adjusted to 12 minutes for medium and 18 minutes for extra large eggs. At the end of the hold time, the eggs were immersed in an ice water bath to stop the cooking process. Soft cooked eggs were allowed to stand, covered, in the hot water for 5 minutes before cooling. In the second method, described by Humphrey *et al.* (9), eggs were heated by immersing in boiling water and removing after 3, 6, 9, 12 and 15 minutes followed by cooling in an ice water bath. At the end of the cook times, one egg was immediately cut open and photographed to record visual appearance at final temperature.

Six-inch solid type T thermocouples were used to monitor temperature in all other cooking methods. The thermocouples were inserted in the yolk of the poached, sunny-side-up and over-easy eggs to obtain data for heating curves. Preliminary trials of sunny-side-up eggs indicated that the slowest area of heating is found approximately 2mm below the membrane surface at the center of the yolk. Temperature measurements of the poached eggs during cooking were taken at approximately the center of the yolk.

Poached eggs were prepared in shallow, teflon coated pans resting in boiling water approximately 25 mm deep. See Figure 2. The pot was covered during the cooking process.

An electric skillet set to 121°C (250°F), preheated and seasoned with a no stick cooking spray was used to prepare the scrambled, sunny-side-up and over-easy eggs. An infrared thermometer was used in monitoring surface temperature of the electric skillet. For scrambling, a 300ml mixture of blended egg was pour into the hot skillet and stirred by intermittently scraping the bottom surface toward the center with a rubber spatula until the eggs had thickened forming soft curds, and no visible liquid remained. For this study, no additional liquid or salt was added to the blended eggs prior to cooking. An infrared thermometer was used to monitor surface temperatures during cooking and a final temperature was

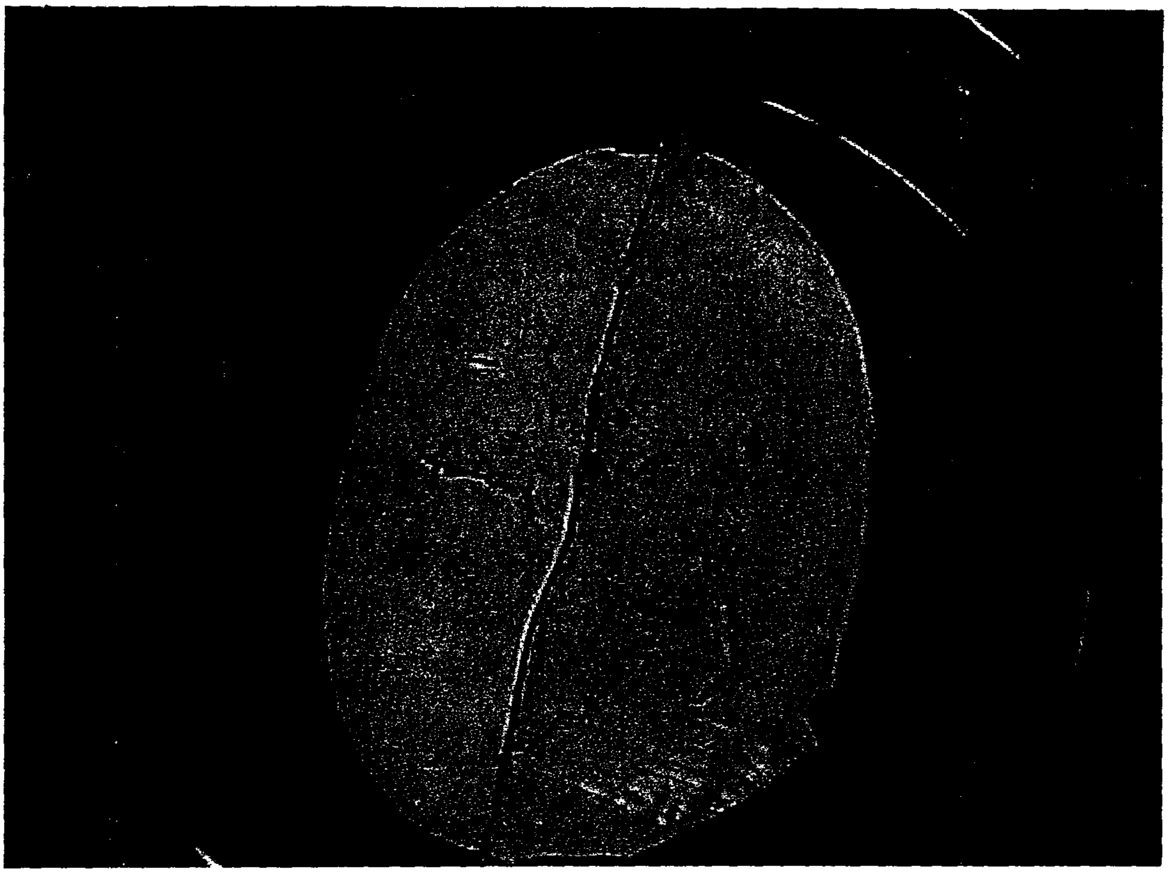


Figure 1. Thermocouple placement in hard cooked egg

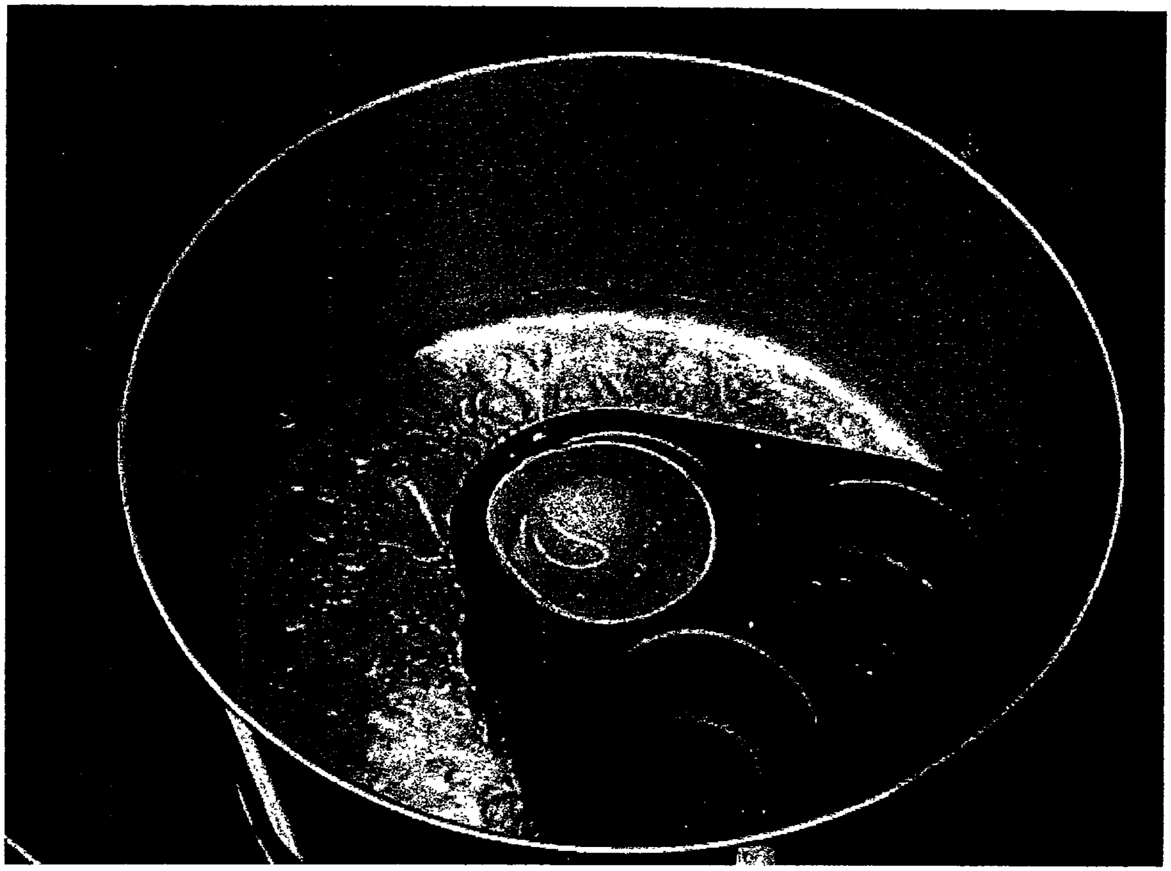


Figure 2. Apparatus used for Poaching

taken with a thermocouple inserted in the thickest portion of scrambled egg immediately at the end of the cook period.

Thermal Process Evaluation:
A procedure outlined by Beloian *et al.* (2) and Patashnik (16) was utilized to evaluate the lethality of th cooking treatments. These calculations were based on the thermal death time (TDT) characteristics an z value of 4.33 reported by Schuman *et al.* (19). The thermal process was estimated by converting cooking temperatures recorded at 0.5 minute equal intervals into equivalent minutes at 60°C (140°F) using the formula:

$$F/t = 1/(\log^{-1}((60-T)/z))$$

Where F/ t = the ratio of time in minutes (F) required to destroy an organism at a selected base temperature (60°C), to the time in minutes (t) required to destroy it at a given temperature. The total lethality of the cooking procedure was derived by a summation of F/ t values. The equivalent time at 60°C is estimated by multiplying the $\sum F/t$ by the equal time interval (0.5 minutes) that the readings were taken. An optimum process time was set by calculating the 5 log cycle reduction in SE recommended by USDA shell egg pasteurization requirements using the D value (0.28 minutes at 60°C Schuman *et al.*) of stationary phase *Salmonella* spp. in yolk. This resulted in a value of 1.4 total minute at 60°C (140°F). The estimated total lethality of each cooking process was then compared to this value These calculations are using a published z value and seem to correspond well with the FDA recommendation of cooking the egg to 63°C (145°F) for 15 seconds.

Results and Conclusions:

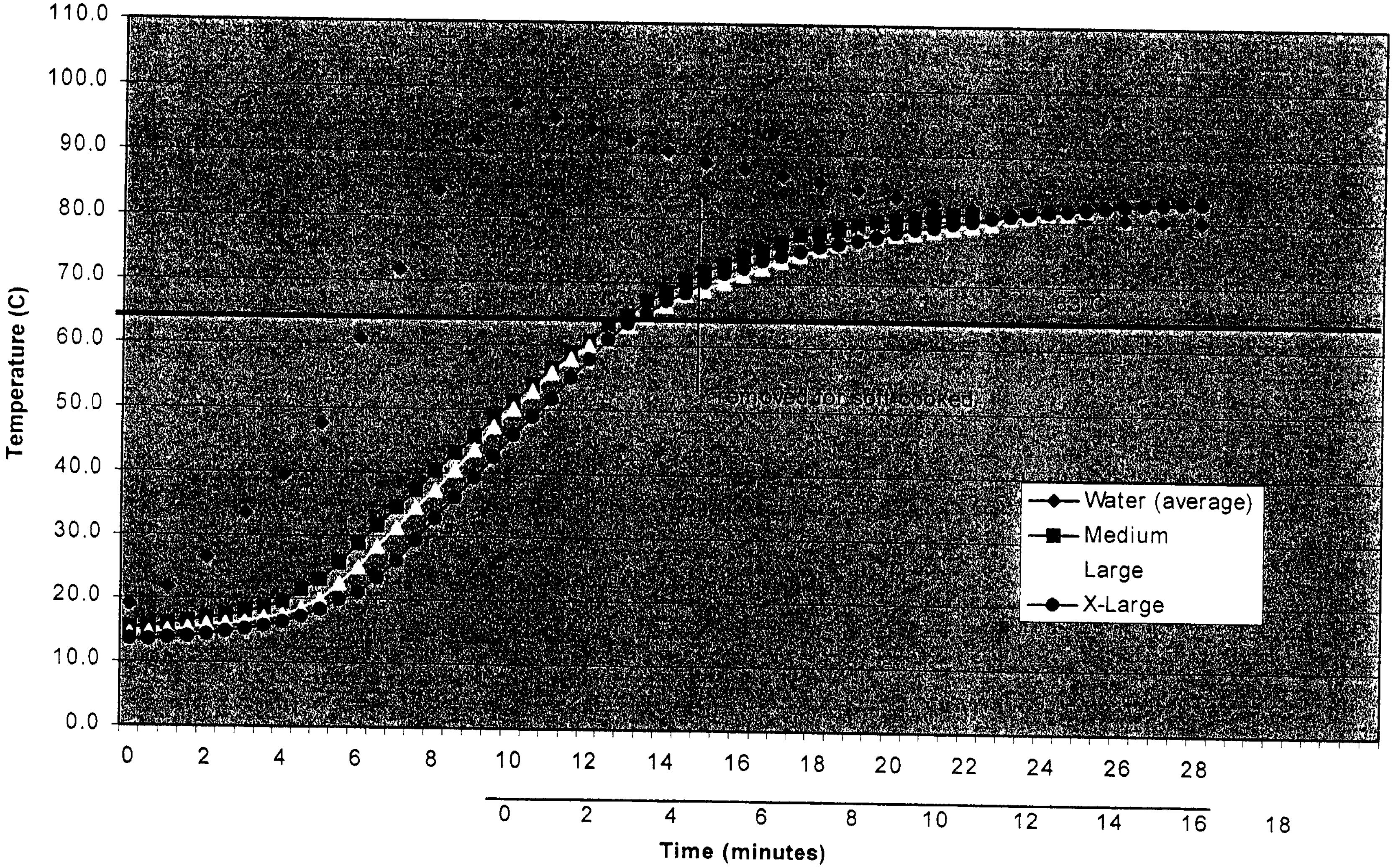
During cooking processes, temperature and appearance of the eggs were monitored and documented. Heating curves shown are for the egg in each set with the slowest heating rate. All eggs were prepared directly from refrigerated storage (4°C). Hard and soft cooked eggs in this study started at a slightly higher initial temperature due to the time required for thermocouple insertion.

Hard and Soft Cooked:
The temperature profiles for hard and soft cooked eggs are shown in Figure 3. (AEB method) and Figu 4. (Humphrey method). Both methods produced an acceptable hard cooked egg with the typical light yellow color, mealy texture (Figure 5) and reached temperatures well in excess of those required to destroy any Salmonella present.

The AEB method has the advantages of a wider margin for error and less shell cracking during cookin When the eggs were placed directly into the boiling water, a range of 9 to 10 minutes was required to reach 63°C. In this study, differences in egg size did not drastically affect temperature penetration rate

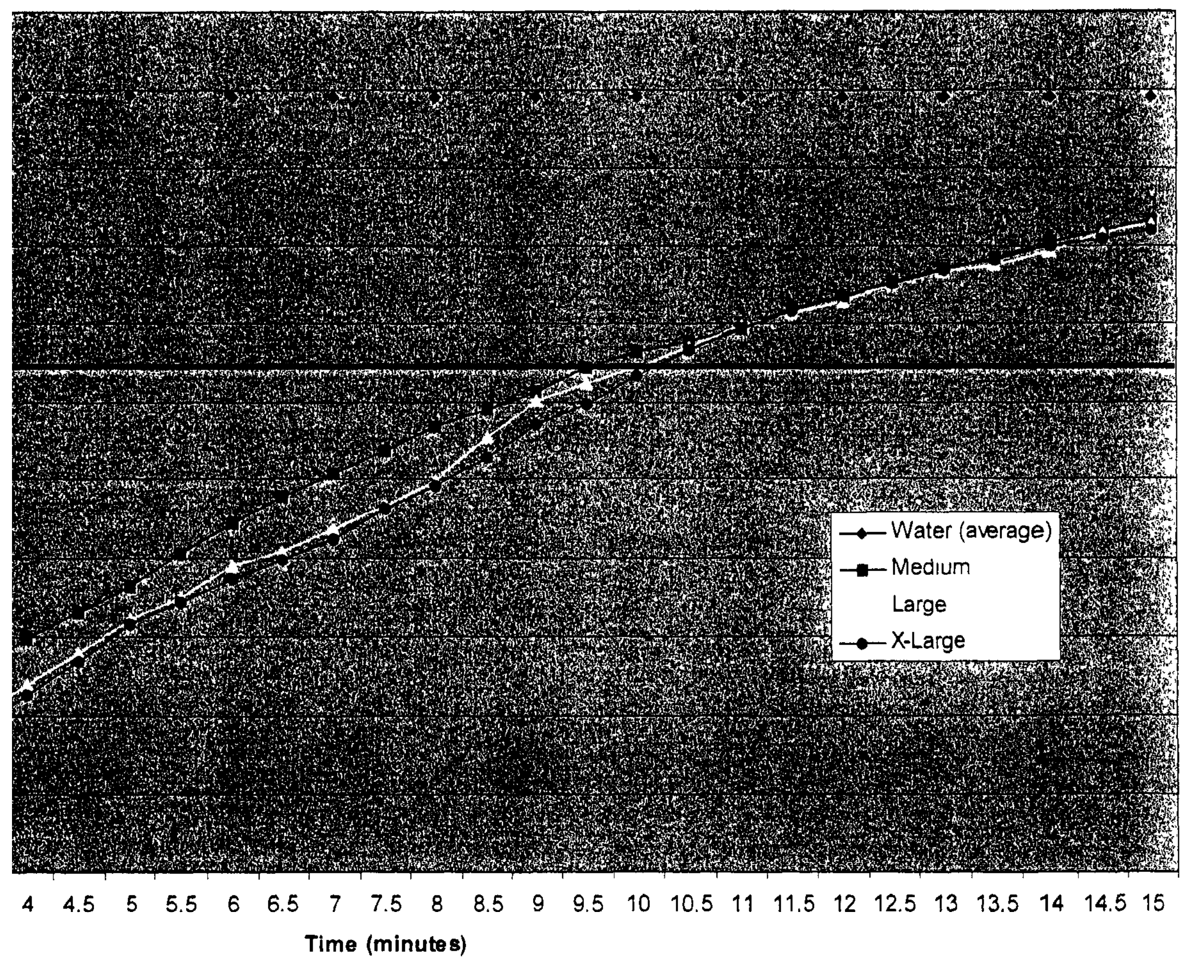
Table 1. is a display of values generated from the thermal process evaluation of a medium sized egg, hard cooked by the AEB method.

Figure 3.
Time / Temperature of Hard and Soft Cooked Eggs (AEB method)



Temperature curves of the yolks of eggs cooked using the American Egg Board method. The water and eggs were brought to a boil (10 minutes), removed from the heat source, and held for 12 min. (medium), 15 min. (large) and 18 min.(x-large). Soft-cooked eggs were removed after 5 minutes.

Figure 4.
Time/Temperature of Hard and Soft Cooked Eggs (Humphrey method)



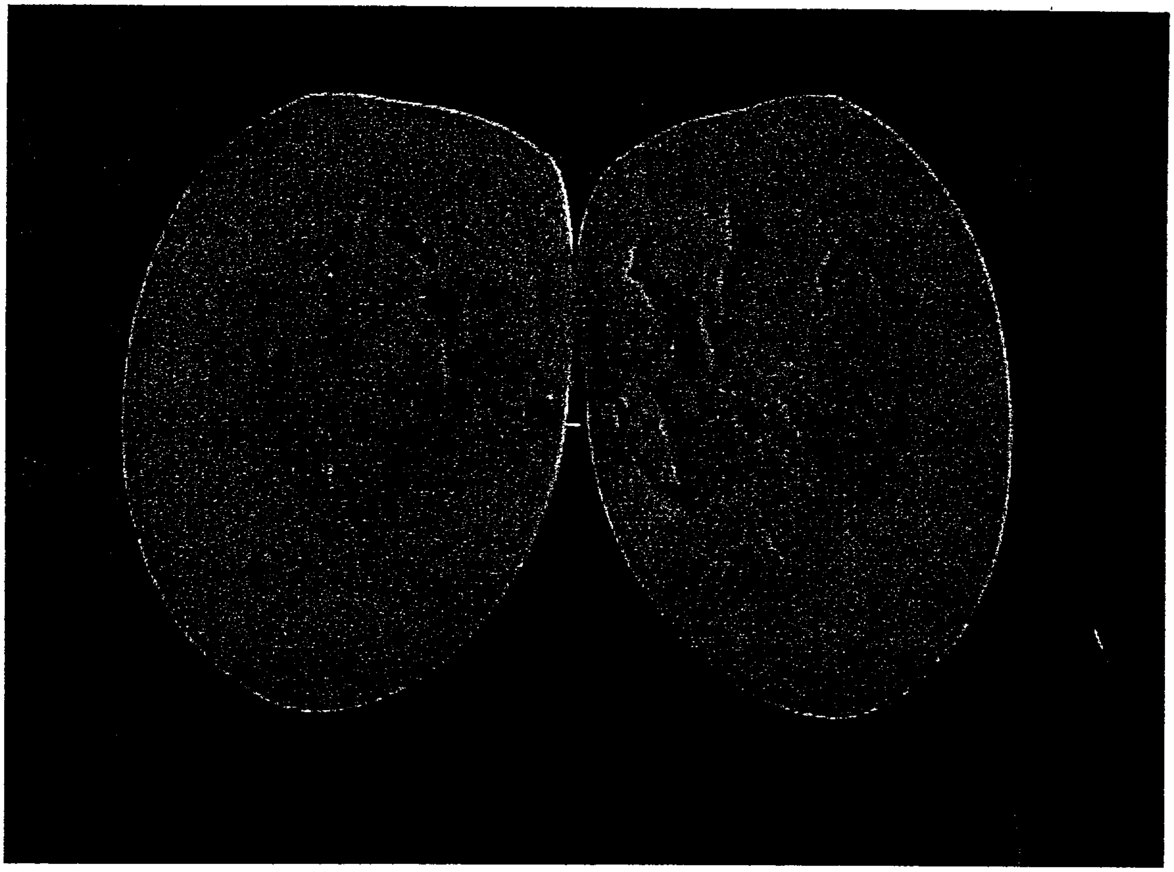


Figure 5. Typical hard cooked egg (AEB method)

Table 1.

Time	Temperature	F/t	∑ F/t	Equiv time at 60C
0	15.3	8.26E-11		
	15.4	8.76E-11		
1	16.1	1.20E-10		
	16.5	1.52E-10		
2	16.9	1.91E-10		
	17.3	2.27E-10		
3	18.0	3.31E-10		
	18.6	4.54E-10		
4	19.6	7.64E-10		
	21.6	2.10E-09		
5	23.1	4.71E-09		
	25.8	1.94E-08		
6	28.9	9.49E-08		
	31.7	4.02E-07		
7	34.6	1.80E-06		
	37.3	7.43E-06		
8	40.3	3.64E-05		
	43.2	0.00015854		
9	45.7	0.00059845		
	48.7	0.00276494		
10	51.4	0.01138106		
	53.9	0.04295932		
11	56.4	0.15754025		
	58.7	0.51470997	0.73	0.37
12	60.7	1.4141292	2.14	1.07
	63.3	5.49420285	7.64	3.82
13	64.7	11.308985		
	67.2	41.472261		
14	68.5	82.9346262		
	70.4	221.371468		
15	71.8	455.65966		
	73.0	860.076826		
16	74.3	1719.94843		
	75.1	2503.48661		
17	76.4	5153.04825		
	77.7	9726.59589		
18	78.0	11566.592		
	78.6	15438.7805		
19	79.2	21832.4303		
	79.8	29141.3493		
20	80.0	32709.4082		
	80.4	41209.6329		
21	80.7	47610.4771		
	81.1	56617.0293		
22	81.2	61740.3874		

As illustrated in Table 1, the minimum equivalent process time of 1.4 total minutes at 60°C (140°F) was not reached until between 12 to 12.5 minutes (2 to 2.5 minutes after removing from heat source), or an internal temperature of approximately 63°C. This temperature is reached prior to the 4-5 minute recommended hold time for soft cooked eggs. A Photograph of an AEB soft cooked egg can be seen in Figure 6. The albumen is soft set and the yolk is a deep yellow and only partially gelled. The center most portion of the yolk is thick, but still flowing. Figure 7 contains photographs of eggs held in boiling water for 9, 12 and 15 minutes. The 9-minute egg reached a minimum internal temperature of 57°C (135°F), which would be considered undercooked. The albumen was not completely set in the

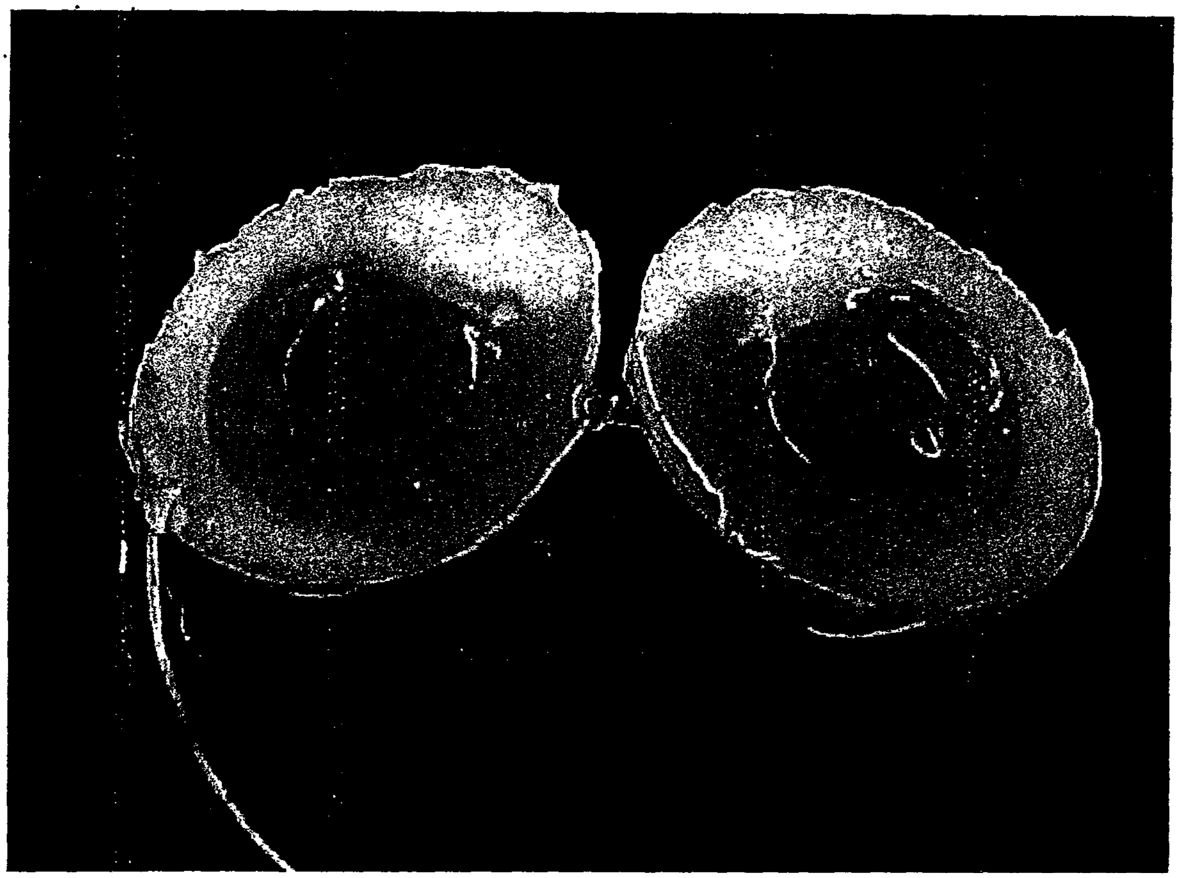
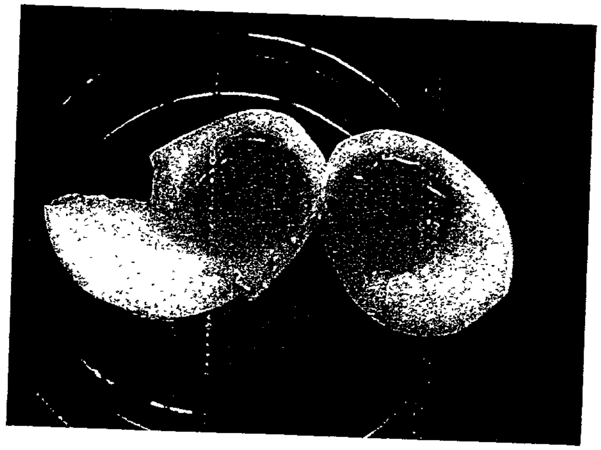
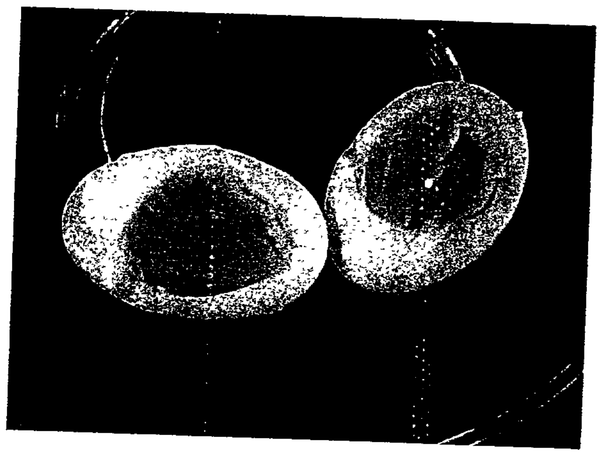


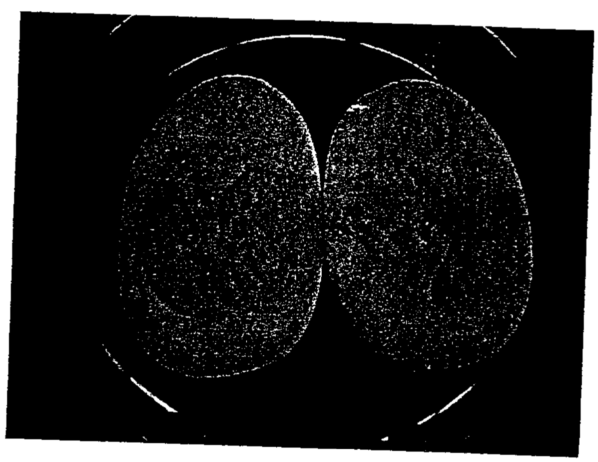
Figure 6. Soft Boiled Egg - AEB Method



9 minute cook time



12 minute cook time



15 minute cook time

Figure 7. Eggs cooked 9, 12 and 15 minutes – Humphrey method

area closest to the yolk and the yolk was dark yellow, thick and runny. The visual appearance is very similar to a soft cooked egg taken to the recommended internal temperature of 63°C (Figure 8). Internal temperatures reached approximately 73°C in eggs held for 12 minutes in boiling water. The yolk was a deep yellow gummy gel that did not flow. The albumen of eggs held in boiling water 3 and 6 minutes had not fully set and the yolks were visually unchanged with temperatures below 45°C (113 °F). A 15-minute hold time produced a typical hard cooked egg. In Humphrey's study (9), viable SE was found in inoculated eggs boiled for 8 minutes but was not present in those held for 9 minutes in boiling water. Initial or final egg temperatures were not reported.

Scrambled:

The temperature of the egg mixtures with initial temperatures of 12-14°C (54-57°F) rose quickly during the scrambling process. After 1 minute, the coolest surface temperature recorded was 48°C (118°F) and after 2 minutes, even the most liquid portions had reached a temperature of 67°C (153°F). Three minutes produced softly coagulated curds with no visible liquid and final temperatures of 74 – 80°C (165-176°F), which could be considered safe. Beloian and Schlosser indicated that the use of very large egg masses in scrambling could pose problems with heat penetration (2). Humphrey *et al.* (9) reported that when SE inoculated egg mixtures (with added milk) are scrambled on high heat until there is no visible liquid, a final temperature of approximately 84°C is reached and no SE was recovered. A final temperature of 74°C was recorded when cooked to the same visual end-point over medium heat, and viable SE were still present.

Poached:

The heating curves for poached eggs, shown in Figure 9, indicate cooking times ranging from 6 to 7 minutes to reach an acceptable temperature of 63°C (145°F). When an internal temperature of 63°C is reached, the albumen is soft set and the yolk has turned dark yellow with about half of the volume gelled and the rest liquid (see Figure 10). If the egg is held 8 minutes, minimum internal temperature is approximately 78°C (173°F) and the yolk has no liquid portion and the outer sections are starting to turn light yellow as seen in a typical hard cooked egg (Figure 11).

Sunny-side-up:

Eggs cooked sunny-side-up, uncovered and without basting, do not reach a safe internal temperature within an acceptable time frame. Under our cooking conditions, the thin albumen set between 1 to 2 minutes and the thick albumen was opaque and completely soft set at approximately 5 minutes. After 10 minutes of frying, the cold spot in the yolks were all below 45°C (113°F) as seen in Figure 12. The majority of the yolk was gelled, with just a small portion of liquid near the top center (Figure 13). The albumen was extremely overcooked and rubbery. For fried eggs, the cooking surface temperature most often recommended is 121°C (250°F). Surface temperature of the electric skillet cycled between 239-272°F when set at 250°F, this temperature may be too low and not realistic for typical consumer compliance. If the egg is removed when the albumen has completely set, approximately 5 minutes, the temperature of the cold spot in the yolks ranged from only 20°C to 30°C (68-86°F). An example of this egg can be seen in Figure 14. During cooking, especially frying, the coagulating layers of the egg change thermal conduction properties. Without agitation, boundaries are formed at the constantly moving solid-liquid interface. These boundaries act to insulate and slow the heating rate in the remaining liquid portion. This could protect any SE from the cooking heat.

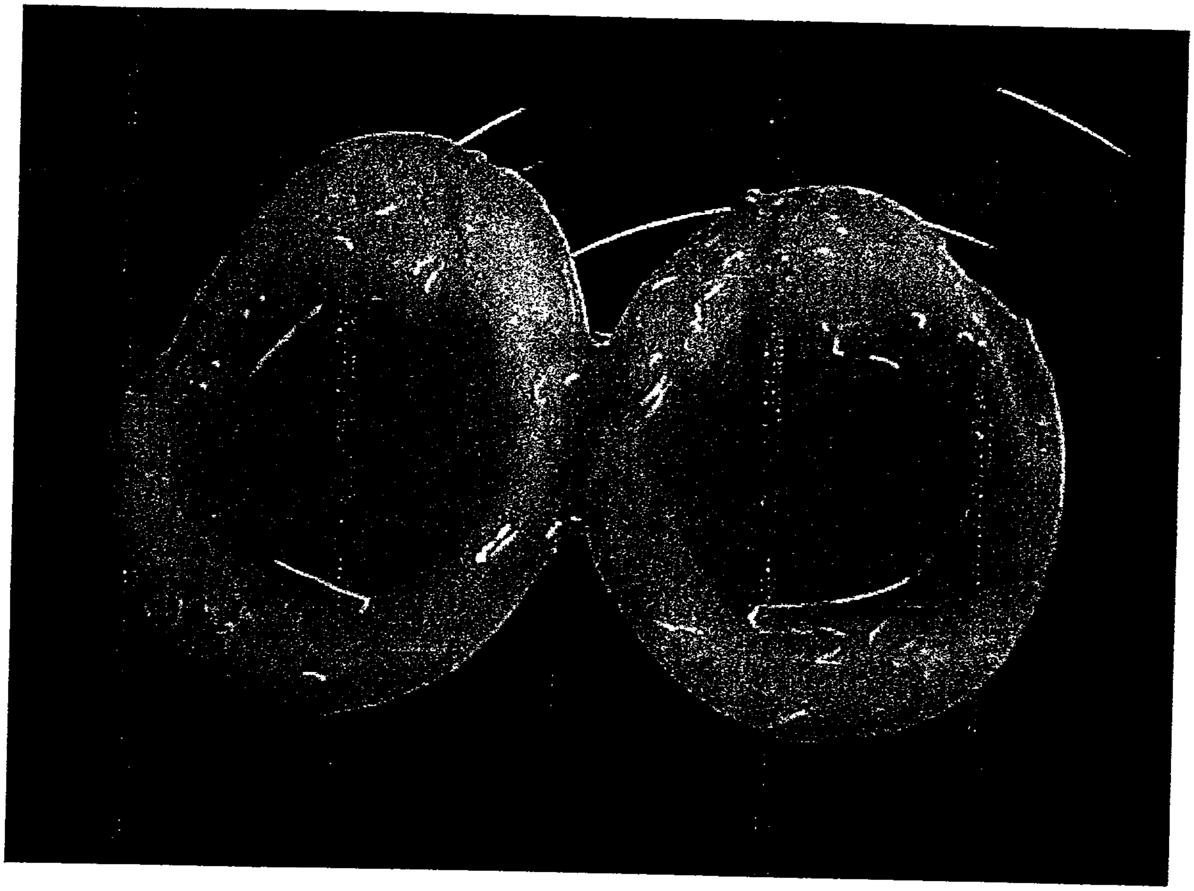


Figure 8. Soft cooked to 63 C

Figure 9. Time/ Temperature of Poached Eggs

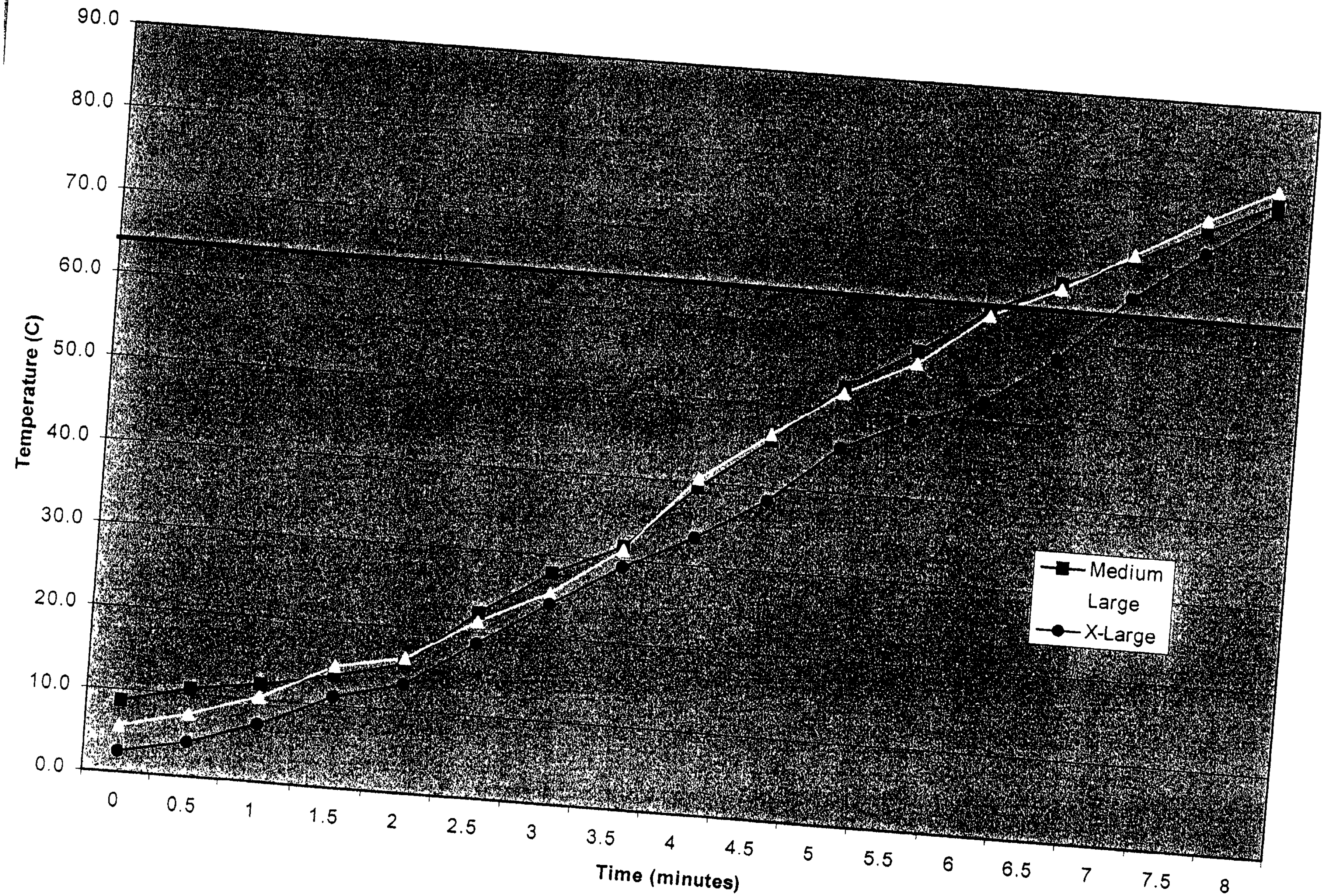
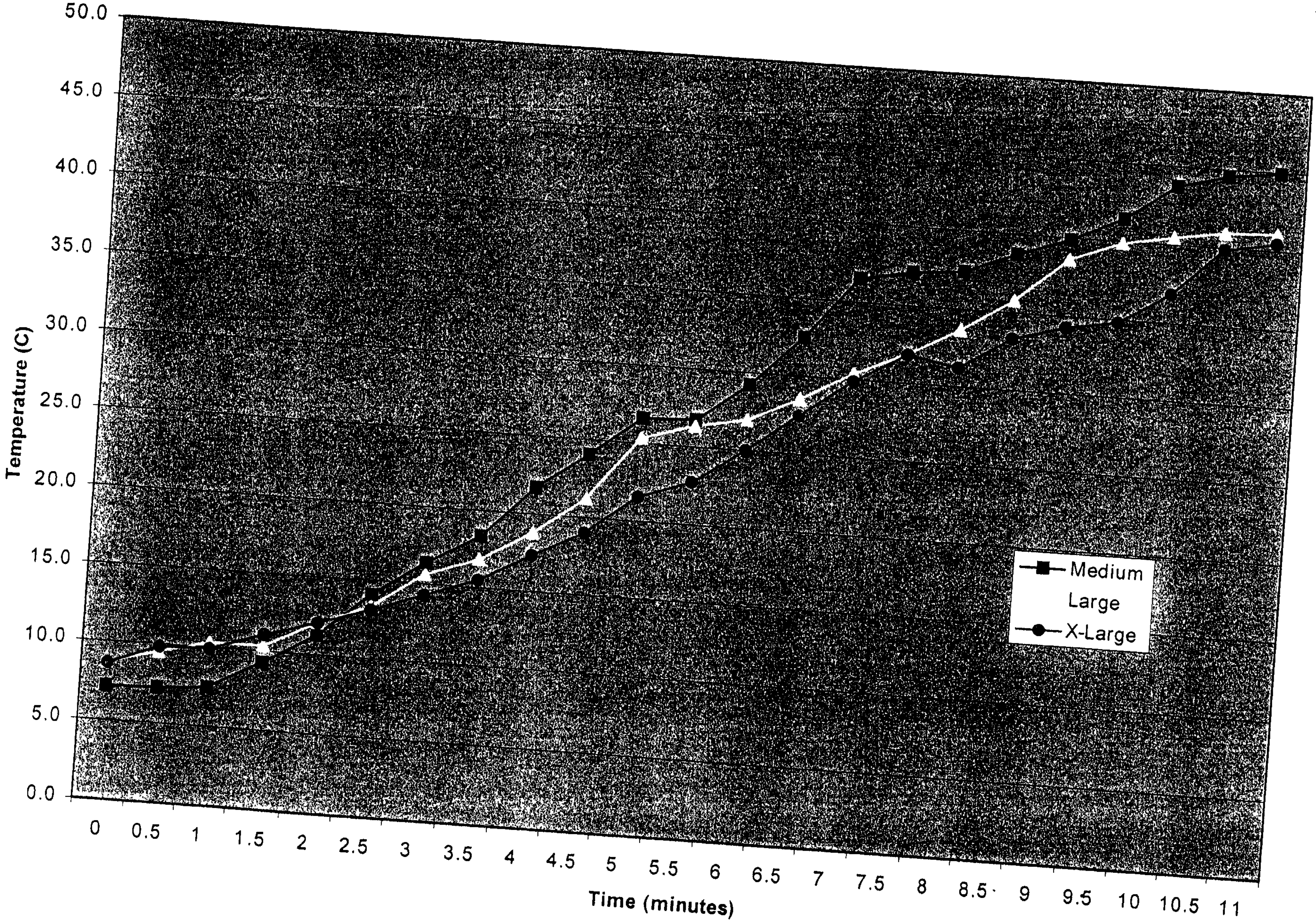


Figure 10. Poached Egg taken to 63 C

Figure 11. Poached 8 minutes

Figure 12. Time Temperature of Eggs - Sunny-Side-Up



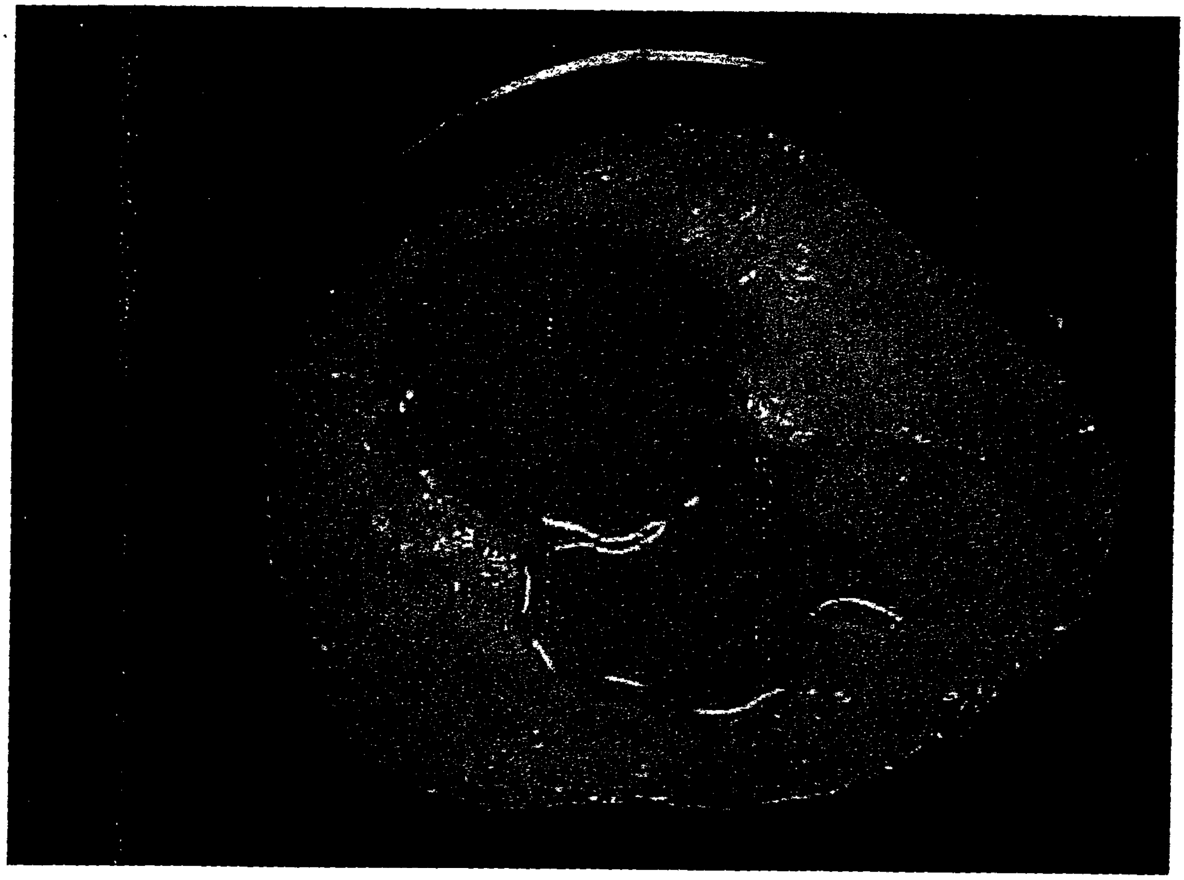


Figure 13. Sunny-Side-Up Egg Cooked 10 minutes

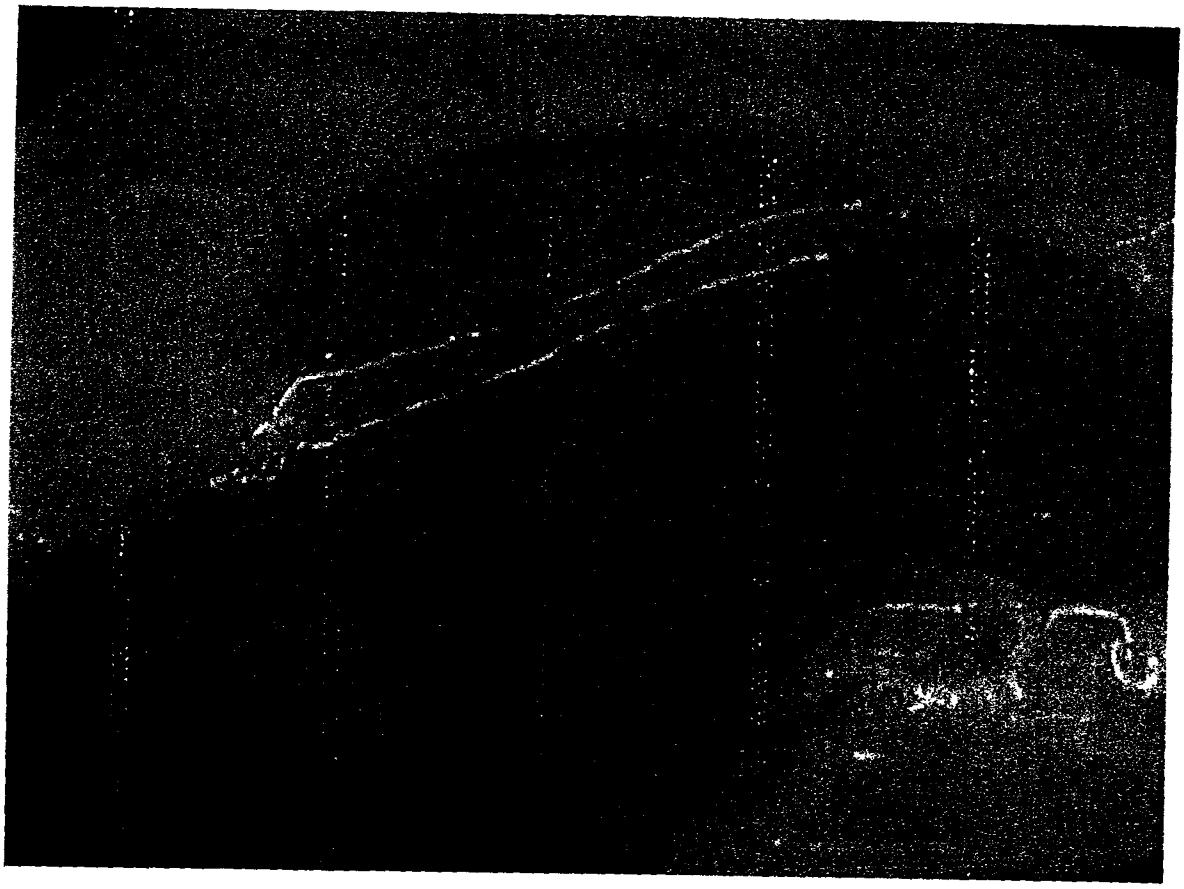
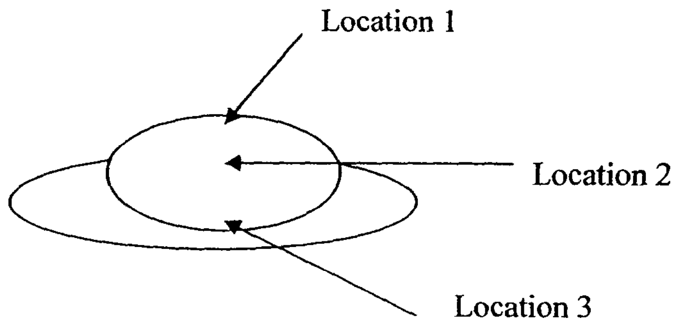


Figure 14. Sunny-Side-Up Egg Cooked 5 minutes

Over-easy:
Monitoring the temperature of the cold spot in over-easy eggs proved to be very difficult. The cold spot in the yolk is constantly moving. The eggs were fried five minutes on one side prior to turning. During the initial five minutes, the heating curves are the same as seen in eggs cooked sunny-side-up. When turned, the temperature of the previously heated areas, that are now on top, start to cool. In an effort to understand the temperature patterns better, readings were taken in three locations within the yolk as presented when broken out onto the cooking surface.



The temperature in the center of the yolk may be the best indicator of heat treatment. Initially the temperature at Location 1 increases at a faster rate than the center position because the yolk is equilibrating to room temperature. After reaching that temperature and until the egg is turned. the cold spot migrates upward toward Location 1. During the turning process there is agitation of the yolk contents. The amount of agitation and the viscosity and quantity of yolk that is still fluid all affect the degree of mixing. After turning, we were unable to obtain replicable temperature measurements. The temperature at Location 2 ranged from 20°C to 65°C (68-149°F) immediately after turning. Precise recommendations would be difficult to make based on these data. Figure 15 is a photograph of an egg that had been fried on one side until the albumen was completely set and then turned and held an additional 2 minutes. Final temperatures at Location 2 ranged from 51°C to 83°C (124-182°F).
The cooking times required to fry eggs in this study are significantly higher than those reported by Humphrey *et al.* (9) or Baker *et al.* (1), when the time was left up to a cook's discretion. Typical consumers fry eggs between 1 to 5 minutes, which does not provide adequate heat treatment.

Under normal conditions, it is not possible to cook an intact yolk to an over-all temperature of 63°C. When the internal temperature has reached 63°C, the majority of the yolk is at a much higher temperature and has solidified. Recommending specific minimum cooking times or temperatures to prepare yolks that are still liquid may not be feasible. Many factors can influence the heating rate for eggs. Initial temperature of the egg, cooking equipment, ratio of water to eggs, and even altitude, which influences boiling temperature, could be factors during cooking. In preliminary trials, a ceramic glass, solid surface cook-top range was used. This range proved to be slower to heat than most conventional

Figure 15. Over Easy – 5 minutes and then turned for two minutes

electric or gas ranges, taking as much as twice the time to bring samples to temperature. In addition, recommendations state to bring water and eggs to a "boil". There are wide ranges of times and water temperatures that consumers could visually consider to be "boiling". Even egg freshness or quality determines albumen and yolk height and the amount of spreading at breakout. These geometric parameters could affect heating rates during frying or poaching.

As a whole, consumers do not measure temperatures during cooking. When Saeed and Koons (18) had typical consumers prepare inoculated eggs as they would at home, a broad range of times and temperatures were recorded and they found none of the common cooking methods eliminated SE organisms from the artificially infected eggs. Baker (1) has reported similar results.

Several referenced studies have investigated the time / temperature relationship of eggs under simulated domestic cooking conditions (1, 2, 3, 9, 11, 18). Due to the location that temperature was measured and some of the factors listed above, these researchers report a wide variety of final temperatures reached. A consumer would have even more difficulty in monitoring cooking temperatures than in a controlled research setting. Even the recommended safe temperature of 63°C that is supported in this paper has been challenged. Pavic *et al.* (17) concluded that a yolk temperature of 75°C must be reached to achieve the complete destruction of SE. This would preclude the use of eggs with less than solid yolks.

We feel that the recommended minimum temperature of 63°C for 15 seconds will provide adequate heat treatment with a wide margin of safety for the egg consumer. However, the practical measurement or description of a visual cue to this temperature may not be feasible. If consumers demand a yolk that is less than solid, soft cooking and poaching seem to allow for the most even heat penetration that would result in a yolk that is at least partially liquid when the cold spot has reached 63°C. Fried eggs should definitely be cooked on both sides, basted or in a covered pan.

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